TRANSACTIONS of the AMERICAN FISHERIES SOCIETY

April, 1959

VOLUME 88

NUMBER 2

Trout and Trout Hatcheries of the Future[1]

KEEN BUSS

Benner Spring Fish Research Station, Pennsylvania Fish Commission

ABSTRACT

Possible and probable methods for improvement of fish hatchery management and production of trout are presented. It is concluded that in the future application of known information and further research will result in more efficient and more mechanized fish rearing and distribution; in better diets and feeding methods; in improvements in disease control; and in development of improved strains of fish. The literature on these topics is reviewed.

INTRODUCTION

There is reason for disagreement when anyone discusses what will occur in the future. However, that there is room for improvement and that there will be improvement in trout and trout hatcheries of the future cannot be denied. Economy is the mother of improvement in fish culture. If fish culture, and particularly trout culture, is to continue to be a tool of fishery management more economical methods must be found.

Labor, fish food, maintenance and operation are the major costs of fish culture (Haskell, 1952). Industry and agriculture have given us a clue as to how to increase and improve the product at a lower cost. The competitive nature of industry has helped to speed up research and automation in almost every aspect of manufacturing. Likewise, mechanization, better nutrition, and improvement of breeding stock are responsible for the phenomenal advancement of agriculture.

During the first forty years of this century, fish culture did not keep pace with industry and agriculture. This is due to many things such as administrative politics, lack of competition and therefore a loss of incentive, insufficient biological information concerning methods of management, the pressure for maximum production, and among others, the lack of research funds and facilities.

During the last twenty years, and particularly in the last ten years, all branches of fishery science have attempted to duplicate the advances of industry and agriculture through research by borrowing freely from these sciences. In basic research lie the clues as to how the trout hatchery of the future can be made an economical tool of fishery management. The opinions in this paper, and they are opinions, are based on the past findings in fishery science and other related fields, and also, the author's personal experiences in research at the Benner Spring Fish Research Station at Bellefonte, Pennsylvania.

HATCHERY CONSTRUCTION

One of the determining factors in cost of rearing fish is the construction of hatcheries. More complete utilization can be obtained from a long raceway since there are less screens to clean, water flow is uniform without dead areas, and one man can feed more trout. At the Benner Spring Fish Research Station (Buss, *et al.*, 1953), twenty-three tons of trout were raised in one season in a raceway 0.55 of a mile in length. One man fed and cared for

[1]Presented as a contribution to the panel of "Future Fish Culture" at the 88th Annual Meeting of the American Fisheries Society, Philadelphia, Pennsylvania, September 8, 1958.

these fish. This dirt raceway was not cleaned until it was drained and the fish removed. Whether there is more bacterial decomposition in dirt raceways than concrete raceways is only conjecture, but at the time of draining very little undecomposed organic matter was found. Dirt raceways are of simpler construction and easier to build. Also, raceways will be more efficient to mechanize than ponds.

At present, few hatchery buildings utilize more than about 8 to 10 inches of the available vertical space. This is the depth of the troughs now being used. The growing trend, of course, is to make use of the additional space. Vertical egg incubators (Lindroth, 1956; Burrows and Palmer, 1955) and the jar culture of trout eggs (Buss 1959a, 1959b), along with the use of better fungicides, will not only utilize much of the vertical space in a hatchery but will also eliminate most of the egg picking.

Vertical space can also be used for the rearing of fry and fingerlings and this will mean that more young trout can be held in the building until the spring shipments provide space outdoors. The use of fifty-five gallon drums for fry rearing is now being tested at Benner Spring. They are modified and function on the same principle as the warm water hatching jar—the water being fed through a pipe to the bottom of the drum which allows even water dispersal among the fish. The water spills out at the top. Success of this experiment would mean that the holding capacity of the building would be increased six times. Thus, the hatchery building of the future may be smaller but the space will be used more efficiently and heating and maintenance costs will be lowered.

MECHANIZATION OF HATCHERY PROCEDURES

One of the greatest lags in trout culture is in the field of automation and improved hatchery techniques. Why this lag should exist is not fully understandable. Kingsbury (1951) and Haskell (1952) recorded that over forty per cent of the total fish cultural budget is consumed by personal service. This undoubtedly used the major portions of the money allotted, yet as Haskell (1952) noted, the labor costs have, in general, been considered much less carefully than the economics of fish food.

Automation and improved hatchery techniques will undoubtedly save much of the cost of labor in fish culture. Time-consuming seasonal tasks should generally lend themselves very easily to mechanization and streamlining. In many instances the basic principles have bee worked out; but modifications are needed. I other instances, many mechanical features hav been adopted by individual hatcheries or state but have not found widespread use.

Below are listed some of the labor consun ing chores which have been subject to mechan zation, or will be, in trout hatcheries of th future.

Screen cleaning and automatic water regulatio

Cleaning screens and adjusting water flov are important to the survival of the fish ar necessitate constant attention. Self-cleanir screens and automatic water gates (Whal *et al.*, 1956) would eliminate much of the tasks.

Feeding

Pellets lend themselves very well to mecha ical feeders. Not only will the feeders sa time and money, but by using a timing attac ment, fish can be fed over a long period a at more frequent intervals than is customa with hand feeding. They can also be fed the early morning and late evening during t hot summer months when trout naturally fe the best. Twenty-four hour feeding duri summer may prove of value.

Fish collecting

Collecting fish with seines from hatche ponds and raceways requires substantial ma power and repetition. Efficient electro-metho of fish collection will not only be a boon fish culture but to management as well. The could very well be developed in hatcheri Work by Lennon and Parker (1955) a many others have laid the groundwork for more efficient unit. Based on the prelimina results of work now in progress by the Fi and Wildlife Service, it is reasonable to pr dict that hatchery fish will not only be c lected from weed-choked ponds and racewa but also will be subject to selection. For e ample, it has been demonstrated that puls DC current of various wave shapes and f quencies have selective effects on differe species of fish and on different size ranges a given species. It is obvious what the electr method of fishing will mean to fish culturi when it is fully developed.

Weed control

Control of algae and of higher aquatic plar is a perennial problem. At present, it is di

cult to control plants in running water because of the contact time necessary. Species-specific herbicides like those developed for terrestrial plants may very well find application in an aquatic environment. Pelleted herbicides giving controlled rates of dissolution may be the answer in running water.

General maintenance

Use of a tractor and attachments will speed up general maintenance chores. At present at the Benner Spring Fish Research Station, the grass is mowed on bank tops with a matt hammer mower. Low banks are cut with a highway sickle-bar mower which will cut at a 45 degree angle. The tractor is also used to pull a transportation unit which can be used as a herbicide sprayer with constant mixing of the chemical through the recirculating unit. The highlift unit is used with modification to lift the mowed weeds from raceways. Undoubtedly many other hatchery chores can be accomplished with a small tractor and the many attachments available.

Transportation units

Most transportation units use either a recirculating system or bottled oxygen. Haskell's (1958) preliminary results have shown that a combination of oxygen and recirculation is more effective. In this manner the oxygen supply is at a maximum and carbon dioxide is removed in the recirculation unit. Refrigeration units or the use of drugs on the transportation unit lowers the metabolism of fish and permits a larger number to be transported (Schultz, 1956). Lightweight metals such as aluminum and lightweight insulation such as styrofoam are known to form a compact unit. It is conceivable that hatcheries with long hauls on good roads will go to a trailer-type unit similar to the large milk transports. This will save drivers, time and many areas can be planted in one trip.

Counting, grading, weighing and loading

Counting, grading, weighing and loading are combined in this discussion because in the future it will probably be one operation. Electronic counters (Anon., 1957), parallel bar graders (Morton, 1956), weighing by water displacement, and conveyors (Leitritz and Macklin, 1956) have all been developed. All that remains is to modify these procedures and combine them into a working unit and these four tasks will be a simplified one-operation chore.

Spawning

In larger hatcheries, mechanical spawning devices will be used. Lindroth (1956) describes a salmon stripper which utilizes water pressure to extrude the eggs. Air pressure and possibly even electricity may be adapted to spawn fish. Electro-stimulation is now being used to collect semen from farm animals (Barker, 1958). The hatchery building of the future may have a spawning "parlor" much like the milking parlor of the large dairies. It is conceivable that one man could spawn four or five females at one time with push-button effort.

DIETS

It has been pointed out by Phillips, *et al.*, (1957) that after years of study, rations for domesticated animals are considered superior to the natural food of these animals, and it is reasonable to expect that as research progresses the food fed to trout in hatcheries will be superior in all respects to natural food.

What in general can be expected of this new food? It will be a complete dry diet either in the form of meals, crumbles or pellets which will be efficient in all types of water and geographic locations. The meat fraction of the diet will be eliminated. The growth and general well-being of the fish will be as good or better than wild fish just as it is with fowl and other farm animals. Conversions of food to fish flesh will be low. Based on a pilot study at Benner Spring, the food cost of raising one pound of trout may be below 15 cents at present cost standards.

Also included in the pellets will be a colorant which will develop the natural or wild color of the species. Studies by Tunison, *et al.*, 1942, have shown that many ingredients will bring out the natural colors of trout. More recent studies at Benner Spring (Buss, 1958) have added other components to this list. Some colorants will produce high colors in trout in less than three weeks.

Brook trout at Benner Spring fed a 100 per cent shrimp diet over a seven month period before spawning produced a higher percentage of viable eggs than those fed the regular hatchery diets of meat and fish or meat and pellets

although growth on this diet was poor. It is probable that the ingredients which were responsible for this higher egg viability will be isolated and included in more complete diets.

Pellets of the future may be mechanically tailored for the type of water area being fed—floating pellets for some areas such as very long raceways, slowly sinking pellets for ponds and short raceways, or heavier pellets for small confined areas.

TROUT DISEASES

Although trout diseases have had more study than those of other fish species, much more can be accomplished with intensified research. The important contributions of the late Dr. H. S. Davis, Dr. Snieszko at Leetown, West Virginia, Dr. Rucker at Seattle, Washington, and others exemplify what accomplishments could be obtained with a concentrated effort. It is necessary to apply the principles now being utilized for men and higher animals such as clinical pathology, including serology, histopathology and other modern diagnostic measures. When these techniques are applied to trout, tools will be available to diagnose and develop treatment for most diseases.

In the future, the prevention of bacterial and virus diseases will be extended with more research on disease resistant strains (Wolf, 1953, use of prophylactic drugs and antibiotics (Snieszko and Bullock, 1957), and possibly the use of various immunization techniques.

In the past, fish pathology has not always had the benefit of immediate adoption of the newest techniques of human and veterinary medicine. Today, many universities are recognizing that fish are ideal organisms to study, and in the future, coordinated efforts may make fish pathology a field of intensified research and a leader instead of a follower.

SELECTIVE BREEDING OF TROUT

Wood (1953) reviewed a century of fish culture and stated that work in the field of fish genetics has never received the attention which it appears to merit. This sums up the situation in trout culture. Everything else being equal, a hatchery is only as good as the strain of trout it produces and rears. Working with a poor strain of trout is analogous to a rancher trying to compete on the beef market by rearing longhorns. The economic outcome is predictable and obvious. Strains of trout must be developed with disease resistance, fast growth, high egg number and viability, vigor, good appearance, high palatability, and the ability to survive under natural conditions. They must also be adaptable to the hatchery at which they are confined.

How can this be accomplished? Again reference can be made to agriculture (Hayes, *et al.*, 1955 and Lush, 1943). The work of these men indicates that one of the most successful methods of breeding in cross-fertilized species has been the combination of inbred lines which have been carefully selected and tested. Refinements within this intraspecific hybridization procedure include top crosses (selected inbred strains crossed to non-inbred strains), three-way crosses (hybrids of two inbreds crossed with a third inbred) and four-way crosses (hybrids of two inbreds crossed with hybrid of two others). Quite detailed procedures for improving existing inbred lines are now being used. These include convergent improvement and reciprocal recurrent selection which are designed to incorporate into each inbred line outstanding traits from the other. It is not generally agreed in agriculture which method is most effective, but all have proven themselves in one field or another. It remains for research in fish culture to prove the best method for trout.

Donaldson (1955) has shown that hybrid vigor results from certain intraspecific crosses. Survival of these hybrids exceeded that of the parent species when planted. This is an indication of what can be done with intraspecific hybrids for other characteristics.

On the horizon is an entirely new field for exploitation—immunogenetics. It is generally agreed that there is a one to one relationship between genes and antigens. Therefore, the detection of antigens provides a useful tool for the study of genes. In the erythrocytes of cattle, 40 distinct antigenic factors have been found. Therefore the different combinations of these antigenic factors which might occur run into the trillions. The possibilities of this technique is limitless for practical genetic application in breeding (Carpenter, 1956).

Comparative fertility and livability have been found to be directly related to blood factors in poultry (Briles, *et al.*, 1957). As the research proceeds, more and more characters will be related to blood types, and by use of blood factors, the performance and characteristics of the progeny will be predictable before crosses are made.

It is highly possible that this technique can be adapted to trout culture for such traits as

disease resistance, growth, viability, etc. Isoagglutinations in fish are being studied by Cushing and Durall (1957) and others. Variations in antigenic factors are being established in fish of the same species similar to blood groups in humans. The study of immunogenetics in trout involves long-term research but by acquiring established blood types from breeders in poultry, cattle and elsewhere, this process may be speeded up.

The development through selective breeding of fish with one or more missing fins would provide a simple method of identifying trout—even at an early age. At Benner Spring, crosses of fish with missing fins have shown this character to be of a quantitative nature. The development of true breeding strains will require time.

The development of rainbow and brown trout which mature at two years of age and which produce large, viable eggs may be a method of reducing the cost of maintaining brood trout. Selected individuals have shown possibilities with this approach.

Exposure of trout eggs to radioactivity may produce a desirable mutation. However, the odds are very high against this occurring.

It can be gathered from this discussion that the field of genetics is unlimited in fish culture. It is also obvious that more research is needed. In the future, it is hoped that more states will turn their attention to the genetical aspects of trout breeding.

HYBRID TROUT

When experiments were first initiated with interspecific hybrid crosses, it was felt that backcrossing the F_1 progeny would offer a means to speed up the advances in selective breeding. Unfortunately, in most cases, there is a sterility barrier (Buss and Wright, 1956). Only the "splake" (lake trout X brook trout) and a few rainbow X brook trout (Buss and Wright, 1958) have shown any degree of fertility. For fishery management purposes, the splake does have some qualities not possessed by either lake trout or brook trout. Probably the most important are that splake can be brought more readily than lake trout, and that the splake ultimately grows larger than brook trout. One splake, held at Benner Spring, in its sixth year of life measured 27 inches and weighed 9 pounds. If the few fertile rainbow X brook trout could be successfully backcrossed to the brook trout, it would be a method of transferring the furunculosis resistance of the rainbow trout into the brook trout. Results of backcrosses of splake to brook trout show that backcrosses can be made and traits transferred without losing the identity of the backcross species. This is an example of what could be accomplished if fertile F_1 progeny of interspecific hybrids are found.

RESEARCH STATIONS FOR FISH CULTURE

Because of the pressure for maximum production, it is impossible to accomplish the needed research at the average state, federal or private hatchery. Fish culture research stations not only afford the research implied by the name, but are also excellent places to institute basic research on many fish management problems because of the confined environments which are available. Also, biologists with laboratory facilities could do many fundamental or academic research problems because of the unlimited sizes and number of fish available. Thus fish culture research stations have a multi-purpose program which will help to make fish culture and fish culture research an economical tool of fishery management.

CONCLUSIONS

Although the subject of trout and trout hatcheries was only touched upon in this paper, it is obvious that intense research in trout culture is greatly needed. As long as there is a demand for trout stocking, and there probably will be for a long time in one form or another, then it should be made as efficient an operation as possible. As stated in this paper, the groundwork for developing greater efficiency in fish cultural practices has been laid either by fishery men or workers in related fields. All that is necessary now is a coordinated research plan between the federal and state organizations. This could be patterned after the Federal Agricultural Research Program. The recent advances in agriculture have come about as a result of attacking problems on a regional and inter-regional basis through this program. A similar arrangement in fisheries with the U. S. Fish and Wildlife Service providing the impetus and coordination would be expected to bring about significant progress. Trout and trout hatcheries of the future, as speculated upon in this paper, would then be a reality in the very near future.

REFERENCES

ANONYMOUS. 1957. Prog. Fish Cult., Vol. 19, No. 2, pp. 94.

BARKER, C. A. V. The collection of semen from bulls, rams, and bucks by electro-ejaculation. Canad. Jour. Comp. Medicine, Vol. 22, No. 1, pp. 3-8.

BIELES, W. E., C. P. ALLEN AND T. W. MILLEN. 1957. The B blood group system of chickens I. Heterozygosity in closed populations. Genetics, Vol. 42, No. 5, pp. 631-648.

BURROWS, R. AND D. PALMER. 1955. A vertical egg and fry incubator. Prog. Fish Cult., Vol. 17, No. 4, pp. 147-155.

BUSS, K. W. 1958. Easter egg trout. Penna. Angler, Vol. 27, No. 9. pp. 12-14.

———. 1959a. Jar culture of trout eggs. Prog. Fish Cult. Vol. 21, No. 1, pp. 26-29.

———. 1959b. Research answers the trout egg incubation problem. Penna. Angler, Vol. 28, No. 3, pp. 2-5.

BUSS, K. W., A. D. BRADFORD, J. E. WRIGHT, JR., AND G. L. TREMBLEY. 1953. Benner Spring progress report No. 3, Penna. Fish Comm., mimeo.

BUSS, K. W. AND J. E. WRIGHT, JR. 1956. Results of species hybridization within the family *Salmonidae*. Prog. Fish Cult., Vol. 18, No. 4, pp. 149-158.

———. 1958. Appearance and fertility of hybrid trout. Trans. Amer. Fish. Soc., Vol. 87, pp. 171-181.

CARPENTER, P. L. 1956. Immunology and serology. 351 pp. W. B. Saunders Co.

CUSHING, J. E. AND G. L. DURALL. 1957. Isoagglutination in fish. The Amer. Nat., Vol. 91, No. 857, pp. 121-126.

DONALDSON, L. AND P. OLSON. 1955. Development of rainbow trout brood stock by selective breeding. Trans. Amer. Fish. Soc., Vol. 85, pp. 147-155.

HASKELL, D. C. 1952. Labor to produce fifty tons of trout: a time study. Prog. Fish Cult., Vol. 14, No. 3, pp. 87-97.

HASKELL, D. C. AND R. O. DAVIES. 1958. Carbon dioxide as a limiting factor in trout transportation. New York Fish and Game Jour., Vol. 5, No. 2. pp. 175-183.

HAYS, H. K., F. R. IMMER, AND D. C. SMITH. 195[illegible] Methods. of plant breeding. McGraw-Hill Co.

KINGSBURY, O. R. 1951. Production statistics an costs in relation to fish hatcheries. Trans. Ame Fish. Soc., Vol. 80 (1950), pp. 148-153.

LEITRITZ, E. AND R. MACKLIN. 1956. Fish esc weigher. Prog. Fish Cult., Vol. 18, No. 4, pp 178-180.

LENNON, R. E. AND P. S. PARKER. 1955. Electr shocker developments on southeastern trout w ters. Trans. Amer. Fish. Soc., Vol. 85, pp. 23 240.

LINDROTH, A. 1956. Salmon stripper, egg counte and incubator. Prog. Fish Cult., Vol. 18, No. pp. 165-170.

LUSH, J. L. 1945. Animal breeding plans. 443 p Iowa State College Press.

MORTON, K. E. 1956. A new mechanically adjustab multi-size fish-grader. Prog. Fish Cult., Vol 1 No. 2, pp. 62-66.

PHILLIPS, A. M., JR., D. R. BROCKWAY, F. E. LOV LACE AND H. A. PODLIAK. 1957. A chemic comparison of hatchery and wild brook trou Prog. Fish Cult., Vol. 19, No. 1, pp. 19-25.

SCHULTZ, *F. H.* 1956. Transfer of anaesthetiz pike and yellow walleye. Can. Fish Cult., N 18, pp. 1-5.

SNIESZKO, S. F. AND BULLOCK, G. L. 1957. Det mination of the susceptibility of *Aeromon salmonicida* to sulfonamides and antibiotics, wi a summary report on the treatment and pr vention of furunculosis. Prog. Fish Cult., V 19, No. 3, pp. 99-107.

TUNISON, A. V., D. R. BROCKWAY, J. M. MAXWEL AND A. L. DORR. 1942. The nutrition of tro N. Y. Cons. Dept., Cortland Hatchery Rep No. 11, 52 pp.

WHALLS, M. J., D. S. SHETTER AND J. E. VONDE 1956. A simplified rotary fish screen and automatic water gate. Trans. Am. Fish. So Vol. 86, pp. 371-380.

WOOD, E. M. 1953. A century of American fish c ture. Prog. Fish Cult., Vol. 15, No. 4, pp. 1 162.

WOLF, L. E. 1953. Development of disease-resist strains of fish. Trans. Amer. Fish. Soc., Vol. pp. 342-349.

Selectivity and Effectiveness of Certain Types of Commercial Nets in the T.V.A. Lakes of Alabama

C. E. WHITE, JR.
Alabama Department of Conservation, Montgomery, Alabama

ABSTRACT

Trammel, riprap and gill nets with nylon webbing of 3-, 3.5- and 4-inch bar measure were fished under supervision by commercial fishermen in the T. V. A. lakes of Alabama to determine effectiveness of such nets for taking rough fish. Several types of sets were used of which the whip-set trammel was most effective followed by the fixed trammel, riprap and gill net. Mesh of 3-inch bar measure was generally most efficient for taking rough fish. During the period November, 1955, through May, 1956, 10,425 fish weighing 42,689 pounds were taken in the several kinds of gear and of these 95.4 percent were rough fish.

INTRODUCTION

Commercial fishing appears, at present, to be he only practical method for harvesting rough sh in large southeastern impoundments such s the T. V. A. lakes which have a total area n Alabama of about 180,000 acres. The pres- nt study was conducted from November, 955, through May, 1956, to determine the electivity and effectiveness for taking rough sh of trammel and riprap nets of 3-, 3.5- and -inch bar measure and of gill nets of 3- and -inch bar measure. The importance of rough sh removal as a management technique to mprove sport fishing has been discussed by Dequine (1952) and Hulsey (1957) who re- ort improved sport fishing following the re- oval of large poundages of rough fish from rge impoundments and lakes. It has also been bserved that major fish kills of rough fish in labama power impoundments have been fol- wed by improved sport fishing. It is, there- re, desirable that more effective and selective pes of commercial fishing devices be de- loped and used so that commercial fishermen ill be able to do a better job of harvesting ugh fish.

ESCRIPTION OF NETS AND FISHING METHODS

During this study, all nets were fished by sident commercial fishermen under the pervision of state fishery biologists. The fish- men determined the manner and locations which the nets were fished, subject to state gulations and laws which required that;) all game fish be returned to the waters m which they were taken with the least ssible injury; (2) all nets be fished 25 feet or more from the water's edge; and (3) no nets be placed in such a way as to extend more than one-half the distance across any creek, stream or slough. To motivate the fishermen they received the commercial and non-commercial rough fish taken in the nets as payment for their labor.

Trammel nets used consisted of three nets attached to a single float and lead line with the two outer nets or walls of 14-inch bar measure of No. 9 nylon seine twine and the inner net or inside webbing of 3-, 3.5- or 4-inch bar measure of No. 3 or No. 4 nylon seine twine. The walls were three meshes deep and the inside webbing was 23 to 31 meshes deep. The same gear was used for both whipped and fixed trammel sets. A fish striking the trammel net goes through the first wall, strikes the inside webbing, pushing it through the wall on the opposite side of the net, thereby forming a pocket which holds the fish until the net is raised.

Riprap nets are similar in construction to trammels except that the walls of the riprap net were only one-half mesh deep while the walls of the trammel net were three meshes deep. The bar measure of the webbing in the walls of the riprap net varied with the depth of the net (distance between the float and lead lines) while the bar measure of trammel nets was fixed at 14 inches. The function of the walls in riprap nets is to allow the inside webbing to hang without tension.

Gill nets used were of standard design and constructed of No. 3 or No. 4 nylon seine twine with mesh of 3- or 4-inch bar measure. In gill nets the larger rough fish usually thresh about and become wrapped up in the net.

Two general types of sets, whip sets and fixed sets (White 1955) were used during the study. Only trammel nets were used for whip sets while riprap, gill and trammel nets were used for fixed sets. The fixed set (Figure 1F) was fished in a straight line generally perpendicular to the water's edge. In the fixed set heavy weights were tied to each end of the net to hold it in place for 24 hours or longer depending on the poundage of fish caught, weather and other conditions.

For whip sets only trammel nets were used. In shallow water the whip sets were usually made in the shape of a semi-circle (Figu 1A) with the concave side of the net towa the water's edge. To whip such a semi-circu trammel set a helper paddles the boat n and inside the trammel net while the fish man, standing in the front of the boat, be or whips the water with a long limber po The fish move away from the disturbance a become entangled in the trammel net. As so as the fisherman is through whipping, the is raised, the fish removed, and the net pla in the boat. The fishermen then move to a n location and another set is made.

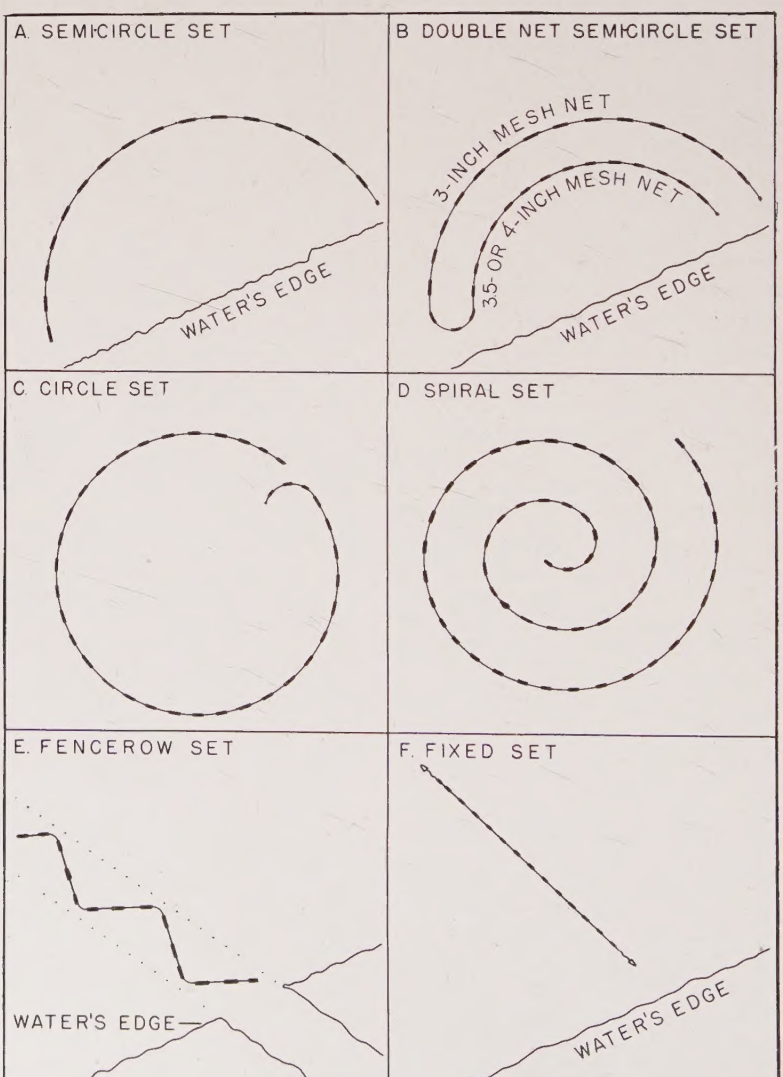

FIGURE 1.—Net set positions used for commercial fishing in T. V. A. waters. A, B, C, D, and E are t mel net positions used for whip sets. F shows position of fixed sets for trammel, riprap and gill nets

Many of the whip sets considered were made using two trammel nets set nearly parallel (Figure 1B). The inside webbing of the outer net of this type of semi-circular set was 3-inch bar measure while the inside webbing of the inner net was 3.5- or 4-inch bar measure. The inner and larger mesh net was placed from 5 to 20 feet in front of the smaller mesh net. The purpose of this type of semi-circular set was to determine the percentage of fish that would pass through the larger mesh (3.5- or 4-inch) and would be caught in the smaller mesh (3-inch).

Whip-set trammel nets also were used in making "fencerow" and circle sets. The "fencerow set" (Figure 1E) was made in deeper water, such as an old pre-impoundment channel. The net was set in a zigzag fashion from one edge of the channel to the other. The circle set (Figure 1C), as the name indicates, was made around an area believed to contain a concentration of fish. A variation of the circle set was used in some cases with the net set as a spiral (Figure 1D). In making a spiral set the outside turn was set first and then the successively smaller inner turns.

Since similar lengths of netting of each mesh size were not used, the average number of pounds of fish taken with 100 yards of net per day was used to measure the relative effectiveness of each type of fishing. A 100-yard-net-day for fixed nets is defined as 100 yards of netting fished for a period of 24 hours. When whip sets were used, several sets were usually made each day. During the experimental fishing the total number of sets made with 3-inch bar-measure whip-set trammel nets in 48 days was 279; for an average of 5.81 sets per day. A 100-yard-net-day for whip-set nets is defined, therefore, as 100 yards of netting fished the average number of sets per 24-hour period.

CATCHES WITH DIFFERENT TYPES OF NETS

A total of 10,425 fish and turtles which weighed 42,689 pounds was taken in all experimental nets fished from November, 1955, through May, 1956. A list of the species of fish is given in Table 1. The predominant rough fish taken were carp, buffalo, catfish, carpsucker and gar which made up 35.1, 30.8, 8.5, 8.3 and 5.7 percent of the total weight, respectively. Turtles constituted 4.4 percent of the total weight. Principal game fish caught were white crappie, white bass, and largemouth bass. These made up 3.6, 0.6 and 0.4 percent of the total weight, respectively. Sauger and bluegill were also taken but each comprised less than 0.05 percent of the total weight.

Whip-Set Trammel Nets

The catches made with whip-set trammel nets indicated that commercial fishermen could greatly increase the harvest of rough fish by the use of this fishing technique and especially by using the 3-inch bar-measure trammel net. The average catch of 3-inch bar-measure trammel nets was 163 pounds of rough fish per 100-yard-net-day; 114 pounds more than the average catch for trammel nets of 3.5-inch bar measure and 138 pounds more than for trammel nets of 4-inch bar measure (Table 2). Carp, buffalo, catfish, carpsucker and gar made up 93, 83, and 89 percent of the total

TABLE 1.—*Fishes taken from T. V. A. lakes of Alabama with trammel, riprap and gill nets from November, 1955, through May, 1956*

Common name	Scientific name
Bluegill	*Lepomis macrochirus Raf.*
Buffalo	
Bigmouth	*Megastomatobus cyprinella* (Valenciennes)
Black	*Ictiobus niger* (Raf.)
Smallmouth	*Ictiobus bubalus* (Raf.)
Carp	*Cyprinus carpio* Linn.
Carpsucker	*Carpiodes* spp.
Catfish	
Blue	*Ictalurus furcatus* (Lesueur)
Brown Bullhead	*Ictalurus nebulosus* (Lesueur)
Channel	*Ictalurus lacustris* (Walbaum)
Flathead	*Pylodictis olivaris* (Raf.)
Drum	*Aplodinotus grunniens* Raf.
Gar	
Longnose	*Lepisosteus osseus* Raf.
Shortnose	*Lepisosteus platostomus* Raf.
Spotted	*Lepisosteus productus* Cope
Largemouth bass	*Micropterus salmoides* (Lacepede)
Redhorse	*Moxostoma* sp.
Sauger	*Stizostedion canadense* (Smith)
Shad	
Gizzard	*Dorosoma cepedianum* (Lesueur)
Threadfin	*Signalosa petenensis* Everman and Kendall
Skipjack	*Pomolobus chrysochloris* (Raf.)
Spoonbill	*Polyodon spathula* (Walbaum)
White Crappie	*Pomoxis annularis* Raf.
White Bass	*Lepibema chrysops* (Raf.)

weight of fish caught, respectively, in whip-set trammel nets of 3-, 3.5- and 4-inch bar measure (Table 3) and game fish constituted only 3, 1 and 1 percent of the weight of fish, respectively.

In double whip sets in which the larger mesh trammel net was placed in front of the smaller mesh trammel net, 3,180 fish that weighed 12,708 pounds were taken in the 3- and 4-inch nets and 673 fish that weighed 2,599 pounds were taken in the 3- and 3.5-inch nets. Of the total weights of fish caught, 88 percent passed through the 4-inch mesh nets while 65 percent passed through the 3.5-inch mesh nets and were caught in the 3-inch mesh nets (Table 4 and 5). The range of the size groups of each species taken in each mesh size overlapped to such an extent that it was not possible to determine the minimum size of each species which could be taken by 3-, 3.5- and 4-inch bar-measure trammel nets.

Fixed Trammel Nets

The average catch of 3-inch bar-measure fixed trammel nets was 28 pounds of rough fish per 100-yard-net-day. This is 2 pounds les than the catch of 3.5-inch mesh nets and 1(pounds more than 4-inch mesh nets. The differ ence in catch of the 3.5-inch mesh and 3-inch mesh was probably due to chance but it is likel that both 3- and 3.5-inch mesh nets were more effective than 4-inch mesh nets (Tabl 2).

Carp, buffalo, catfish, carpsucker and ga constituted 86, 89 and 85 percent of the weigh of fish taken in fixed trammel nets of 3-, 3.5 and 4-inch mesh, respectively (Table 3).

Riprap Nets

Carp, buffalo, catfish, carpsucker and ga together constituted 86, 88 and 80 percent o the total weight of fish captured with ripra nets of 3-, 3.5- and 4-inch mesh. Game fish made up 8, 7 and 0 percent of the weigh taken with 3-, 3.5- and 4-inch mesh net (Table 3). Three-inch mesh riprap nets tool a greater percentage of game fish (8 percen by weight) than any other type fished durin the study.

TABLE 2.—*Average weight in pounds of fish taken per 100-yard-net-day in various mesh sizes of whip-se trammel nets, fixed trammel nets, riprap nets and gill nets from November, 1955, through May, 1956, i T. V. A. lakes of Alabama*

Kind of net	Whip-set trammel			Fixed trammel			Riprap			Gill	
100-yard-net-days	84	18	62	557	114	232	72	37	72	25	27
Mesh, bar measure in inches	3.0	3.5	4.0	3.0	3.5	4.0	3.0	3.5	4.0	3.0	4.0
Rough fish											
Commercial											
Carp	66.19	18.35	8.84	9.90	11.74	2.70	7.13	7.34	1.71	3.72	0.19
Buffalo	50.51	10.22	9.26	8.79	10.00	4.89	7.41	4.50	2.25	3.05	1.70
Catfish	13.29	6.16	3.43	1.95	2.00	1.93	0.56	2.33	2.72	2.74	0.67
Carpsucker	20.95	1.75	0.58	2.58	1.17		2.07	0.16		0.48	
Redhorse	0.18			0.62	0.23	0.01	0.57	0.05		0.20	
Spoonbill				0.34	0.05	0.28	0.04	0.59	1.27	0.24	0.26
Drum	0.51	0.09	0.37	0.07	0.15	0.30	0.03	0.03	0.08	0.02	
Non-commercial											
Gar	5.95	4.61	0.48	2.29	1.92	0.60	0.56	1.47	0.49	1.75	0.67
Skipjack	0.01			0.03	0.04	0.05			0.16		0.04
Shad	0.12		0.02	0.02	0.01	0.02	0.02	0.03	tr*	0.02	0.02
Turtle	5.42	7.89	2.24	0.98	2.60	1.10	0.48	0.27	0.25		
Subtotal	163.13	49.07	25.22	27.57	29.91	11.88	18.87	17.77	8.93	12.22	3.55
Game fish											
White bass	0.24			0.38	0.07	0.01					
White crappie	5.25	0.36	0.03	1.62	0.17	0.05	1.51	0.59	0.02	0.41	0.06
Largemouth bass	0.38	0.05	0.10	0.20	0.01	0.01	0.18	0.60			
Sauger	0.01			0.02	0.01	tr*					
Bluegill	tr*			tr*	tr*						
Subtotal	5.88	0.41	0.13	2.22	0.26	0.07	1.69	1.19	0.02	0.41	0.06
Total	169.01	49.48	25.35	29.79	30.17	11.95	20.56	17.96	8.95	12.63	3.61

* Trace (less than 0.005 pounds per 100-yard-net-day).

In riprap nets an average of 19 pounds of rough fish was taken per 100-yard-net-day with 3-inch mesh. This was 2 pounds more than with 3.5-inch mesh and 10 pounds more than with 4-inch mesh. The effectiveness of riprap nets decreased as the mesh size was increased from 3 to 4 inches. The number of pounds taken per 100-yard-net-day indicated that riprap nets were the third most effective for harvesting rough species of fish (Table 2).

Gill Nets

Carp, buffalo, catfish, carpsucker and gar constituted 93 and 90 percent of the total weight taken, respectively, in gill nets of 3- and 4-inch mesh. Game fish made up 3 and 2 percent respectively of the total weight in the gill nets (Table 3). On the average 12 and 4 pounds of rough fish were taken per 100-yard-net-day in 3- and 4-inch mesh nets (Table 2). Gill nets, although particularly selective for rough fish, were the least efficient net used. However, even in gill nets it was found that as the mesh size increased from 3 to 4 inches the effectiveness of the net decreased.

DISCUSSION

Although there was a difference in the selectivity of trammel, gill and riprap nets for rough fish, the difference was not great enough to be important. The catch of gill and whip set trammel nets was 97 percent rough fish by weight while fixed trammel and riprap nets took 94 percent rough fish. In all three types of gear combined 3-inch mesh nets caught 94 percent rough fish by weight, while 3.5-inch nets took 98 percent rough fish by weight and 4-inch nets caught 99 percent rough fish by weight. Whip set trammel nets were the most effective type of net fished, followed in order of decreasing effectiveness by fixed trammel, riprap and gill nets. In general, as the mesh size increased from 3 to 4 inches the effectiveness of all nets decreased.

TABLE 3.—*Percentage by weight of catch by species taken in various mesh sizes of whip-set trammel nets, fixed trammel nets, riprap nets and gill nets from November, 1955, through May, 1956, in T. V. A. lakes of Alabama*

Kind of net	Whip-set trammel			Fixed trammel			Riprap			Gill	
100-yard-net-days	84	18	62	557	114	232	72	37	72	25	27
Mesh, bar measure inches	3.0	3.5	4.0	3.0	3.5	4.0	3.0	3.5	4.0	3.0	4.0
Rough fish											
Commercial											
Carp	39.2	37.1	34.9	33.1	39.0	22.6	34.7	40.8	19.1	29.4	5.1
Buffalo	29.9	20.7	36.6	29.5	33.1	40.8	36.1	25.1	25.2	24.2	47.6
Catfish	7.9	12.4	13.5	6.6	6.6	16.2	2.7	13.0	30.4	21.7	18.5
Carpsucker	12.4	3.5	2.3	8.7	3.9		10.1	0.9		3.8	
Redhorse	0.1			2.1	0.8	0.1	2.8	0.3		1.6	
Spoonbill				1.2	0.2	2.3	0.2	3.3	14.2	1.9	7.2
Drum	0.3	0.2	1.4	0.2	0.5	2.5	0.1	0.1	0.9	0.1	
Non-commercial											
Gar	3.5	9.3	1.9	7.7	6.4	5.0	2.7	8.2	5.5	13.8	18.5
Skipjack	tr*			0.1	0.1	0.4			1.7		1.0
Shad	0.1		0.1	0.1	tr*	0.2	0.1	0.1	tr*	0.2	0.6
Turtle	3.2	16.0	8.8	3.3	8.6	9.2	2.3	1.5	2.8		
Subtotal	96.6	99.2	99.5	92.6	99.2	99.3	91.8	93.3	99.8	96.7	98.5
Game fish											
White crappie	3.1	0.7	0.1	5.4	0.6	0.4	7.3	3.3	0.2	3.3	1.5
White bass	0.1			1.3	0.2	0.1					
Largemouth bass	0.2	0.1	0.4	0.6	tr*	0.1	0.9	3.4			
Sauger	tr*			0.1	tr*	0.1					
Bluegill	tr*			tr*	tr*						
Subtotal	3.4	0.8	0.5	7.4	0.8	0.7	8.2	6.7	0.2	3.3	1.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Number of fish	3,765	205	279	4,445	577	422	411	115	108	81	17
Pounds of fish	14,197	903	1,576	16,597	3,446	2,776	1,470	670	640	318	97

* Trace (less than 0.05 percent by weight).

TABLE 4.—*The total number and pounds of fish taken from T. V. A. lakes of Alabama with doubl whip-set trammel nets of 3- and 3.5-inch bar measure from November, 1955, through May, 1956*

Mesh, bar measure	3-Inch				3.5-Inch		
Catch	Number	Pounds	E[1]	C[2]	Number	Pounds	E[1]
Rough fish							
Commercial							
Carp	160	687	40.5	67.3	59	334	37.2
Buffalo	115	410	24.1	68.8	39	186	20.7
Catfish	29	130	7.6	53.7	25	112	12.5
Carpsucker	45	125	7.3	79.6	7	32	3.6
Redhorse	1	3	0.2	100.0			
Drum	2	5	0.3	62.5	3	3	0.3
Non-commercial							
Gar	10	70	4.1	45.5	20	84	9.4
Turtle	73	191	11.2	57.0	47	144	16.0
Subtotal	435	1,621	95.3	74.4	200	895	99.7
Game fish							
White crappie	33	66	3.9	95.7	2	3	0.3
White bass	1	3	0.2	100.0			
Largemouth bass	2	11	0.6	100.0			
Subtotal	36	80	4.7	96.4	2	3	0.3
Total	471	1,701	100.0	65.4	202	898	100.0

[1] Percentage of the total weight comprised by each species.
[2] Percentage of the total catch by weight of each species which passed through the 3.5-inch mesh a was caught by the 3-inch mesh net.

TABLE 5.—*Total number and pounds of fish taken from T. V. A. lakes of Alabama with doubled whi set trammel nets of 3- and 4-inch bar measure from November 1955, through May, 1956*

Mesh, bar measure	3-Inch				4-Inch		
Catch	Number	Pounds	E[1]	C[2]	Number	Pounds	E[1]
Rough fish							
Commercial							
Carp	939	4,282	38.2	88.7	92	543	36.7
Buffalo	925	3,643	32.5	87.3	73	531	35.9
Catfish	238	981	8.8	83.3	37	197	13.3
Carpsucker	470	1,551	13.8	97.7	6	36	2.4
Redhorse	1	3	tr*	100.0			
Drum	51	60	0.5	73.2	12	22	1.5
Non-commercial							
Gar	59	373	3.3	93.7	6	25	1.7
Shad	13	14	0.1	87.5	2	2	0.1
Turtle	26	69	0.6	36.1	35	122	8.2
Subtotal	2,722	10,976	97.8	82.5	263	1,478	99.8
Game fish							
White crappie	178	215	1.9	100.0			
White bass	9	16	0.1	84.2	2	3	0.2
Largemouth bass	6	20	0.2	100.0			
Subtotal	193	251	2.2	98.8	2	3	0.2
Total	2,915	11,227	100.0	88.3	265	1,481	100.0

[1] Percentage of the total weight comprised by each species.
[2] Precentage of the total catch by weight of each species which passed through the 4-inch mesh and wa caught by the 3-inch mesh net.
* Trace (less than 0.05 percent by weight).

Although the selectivity of whip-set trammel ets and gill nets was approximately the same, ie catch of whip-set trammel nets averaged 1 pounds more rough fish per 100-yard-net-ay than did gill nets. Therefore, when both fectiveness and selectivity were considered, ie whip-set trammel net was the most efficient et used. Probably, the most important factor iat made the whip-set trammel net so efficient as that the fishermen carried it to the fish ther than setting it and waiting for the fish come to the net. The catches made on three xperimental sets by Starrett and Barnickol 1955) gave proof of the above theory and of ie fact that carp, carpsucker and buffalo tend congregate in large numbers when spawn-g, feeding and, at other times, for unknown asons. In one set 90 pounds of fish were ken all of which were buffalo. In two other s, 554 pounds of fish were taken of which 5 percent was carp. Similar results were ob-rved on several trammel net sets during this study. One was recorded in which buffalo, carp and carpsucker constituted 99 percent of 1,033 pounds of fish taken in one 400-yard set.

LITERATURE CITED

DEQUINE, JOHN F. 1952. Florida's controlled seining program with a discussion of general fish management principles. Fish Management Bull. No. 1. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida, 1-39 pp.

HULSEY, ANDREW H. 1957. Effects of a fall and winter drawdown on a flood control lake. Proc. 10th Ann. Conf. Southeast. Assoc. Game and Fish Comm., pp. 285-290.

STARRETT, WILLIAM C. AND PAUL G. BARNICKOL. 1955. Efficiency and selectivity of commercial fishing devices used on the Mississippi River. Ill. Nat. Hist. Surv. Bull. 26 (4), pp. 325-366.

WHITE, CLARENCE E., JR. 1955. Fish catches with various types of commercial fishing gear used in T. V. A. Lakes from June, 1954, through January, 1955. Proc. Southeast. Assoc. Game and Fish Comm., pp. 80-86.

Ability of Some Salmonids and a Centrarchid to Swim in Water of Reduced Oxygen Content[1, 2]

MAX KATZ[3], AUSTIN PRITCHARD[4], AND CHARLES E. WARREN[5]

Pacific Cooperative Water Pollution and Fisheries Research Laboratories
Oregon State College, Corvallis, Oregon

ABSTRACT

An apparatus was constructed to determine the ability of fish to swim against currents of known velocity in water of various dissolved oxygen content for periods of one or two days. Fish were tested in currents of 0.8 and 1.2 feet per second at dissolved oxygen concentrations of two milligrams per liter and higher. The ability of juvenile chinook salmon (*Oncorhynchus tshawytscha*) to resist the above currents is in part dependent on their size. Only chinooks over fifty millimeters in total length were able to swim for a day against a current of 1.2 feet per second in water with dissolved oxygen content near the saturation value. In water with a mean dissolved oxygen concentration of 3.0 miligrams per liter or greater, in all experiments but one, juvenile chinook salmon were able to swim for at least one day against a current of 0.8 foot per second. In all tests at mean oxygen concentrations less than 2.84 milligrams per liter, some fish were unable to swim for the one-day period. In experiments at mean dissolved oxygen concentrations above 2.96 milligrams per liter, all juvenile coho salmon (*Oncorhynchus kisutch*) were able to swim against a current of 0.8 foot per second for two days. At oxygen levels between 2.0 and 2.7 millgrams per liter, some of the juvenile cohos were able to swim for two days. Largemouth bass (*Micropterus salmoides*) during September were able to swim against a current of 0.8 foot per second for one day at 25° C. in water having a mean dissolved oxygen content of 2.0 milligrams per liter. In early December, at temperatures of from 15.5 to 17° C., though the bass could swim against the 0.8 foot per second current when the water was nearly saturated with dissolved oxygen, they were unable to do so by the time the oxygen was reduced to 5.0 milligrams per liter.

INTRODUCTION

The minimum concentrations of dissolved oxygen necessary for the maintenance of thriving populations of fish can be determined only through laboratory and field studies which will evaluate the effect that changes of dissolved oxygen have on the biological functions necessary for fish to maintain themselves in their environment. Many studies have been made of the effects of low dissolved oxygen on the survival of resting fish, but there are few reports of experiments in which fish have been forced to maintain sustained activity at reduced levels of oxygen. To obtain information that will lead to better understanding of the concentration of dissolved oxygen required by active fish, a series of studies has been made using an a paratus in which fish are forced to swim various reduced oxygen levels for extend periods of time. However, until more is know of the degree of activity required of fish in n ture, the data reported here will be of uncerta ecological significance.

Other investigators have been interested the ability of fish to swim against currents various velocities; and the influence of te perature and dissolved oxygen on this abili has received some attention. Kerr (195 tested the ability of juvenile chinook salm and striped bass to swim for 10-minute perio against currents created in a flume by circul tion of the water. Fry and Hart (1948 Graham (1949), Job (1955), Gibson and F (1954), and Gray (1957) have made fund mental contributions to the knowledge of t active metabolic rate and the swimming abili of fish through the use of apparatus employi rotating annular chambers. The annular cha ber experiments have usually been of short duration than the experiments discussed he The apparatus described here makes it possib to study the ability of fish to swim under va

---

[1] Technical Paper No. 1114, Oregon Agricultural Experiment Station.

[2] This investigation was supported in part by research grant RG 4352 from the Division of Research Grants, Public Health Service.

[3] Robert A. Taft Sanitary Engineering Center, Public Health Service

[4] Department of Zoology, Oregon State College

[5] Department of Fish and Game Management, Oregon State College

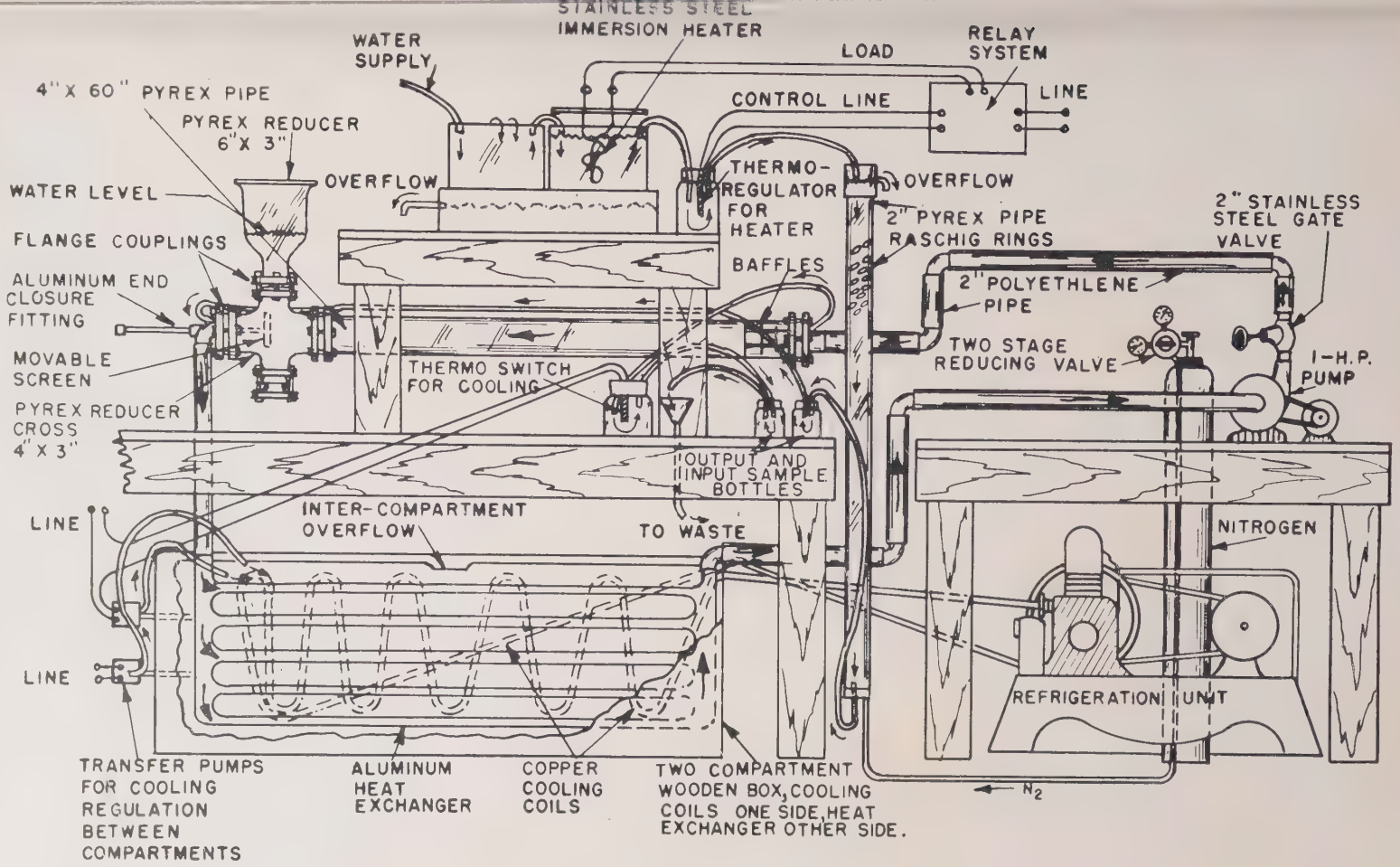

FIGURE 1.—Semi-diagrammatic drawing of apparatus.

ous conditions for long periods of time against actual currents which are essentially rectilinear. In this apparatus, the fish must swim continuously or are forced against a screen.

This study is part of a broader investigation into the influence of the dissolved oxygen content of water upon the survival, growth, development, activity, and movements of freshwater fishes.

APPARATUS AND METHODS

The data reported in this paper were obtained by using a pilot model of the apparatus shown in Figure 1. The pilot model differs principally in not having an automatic cooling system and in not developing currents of as high a velocity.

A current of up to 1.2 feet per second could be developed in the pilot model by circulating water through it with a centrifugal pump. The water was exchanged at a rate of a liter per minute in order to maintain the desired dissolved oxygen concentration in the circulating water. The testing chamber and the tubes to and from the circulating pump contained about 25 liters of water. Bottles were fitted into the incoming and outgoing water lines for taking samples for dissolved oxygen determinations.

A continuous flow of water is first siphoned from an overflow jar into a jar containing an immersion heater controlled by a thermoregulator. The heated water then flows down a second column filled with small ceramic or glass Raschig rings while a countercurrent of nitrogen gas passes upward through the water. By controlling either the rate of water flow by head adjustment or the rate of nitrogen flow with a two-stage regulator, the dissolved oxygen content of the water can be reduced and maintained at the desired level.

Heat generated largely by fluid friction in the centrifugal pump caused the temperature of the water in the apparatus to increase. To prevent this, water returning to the circulating pump was passed through an aluminum heat exchanger immersed in a cooling tank.

The species used for these studies were chinook salmon, *Oncorhynchus tshawytscha* (Walbaum); coho salmon, *O. kisutch* (Walbaum); and largemouth bass, *Micropterus salmoides* (Lacépedé). The salmonids were of both wild and hatchery stocks, and the largemouth bass were wild fish collected from ponds near Corvallis. The total lengths of the chinook salmon ranged from 54 to 121 millimeters, those of the coho salmon from 95 to 124 millimeters, and those of the largemouth bass from 63 to 93 millimeters.

The fish were held at the laboratory in outdoor wooden tanks containing aerated, flowing river water. During the late spring and summer months, when the water temperatures in

TABLE 1.—*The ability of juvenile chinook salmon to swim against a current of 0.8 per second in water of reduced oxygen content for one day*

Date of experiment	Date fish collected	Acclimation history[1]	Temperature range before oxygen reduction (°C.)	Temperature range during experiment (°C.)	Total length of fish (millimeters)	Dissolved oxygen (milligrams/liter)		Number of fish used	Number of fish swimming after	
						Range	Mean[4]		1 day	2 days
7/11/55	21/10/55	18 hours in apparatus[2]	14.0–20.0	19.0–21.0	102–111	2.00–2.10	2.03	3	2	1
11/11/55	21/10/55	24 hours CT[3] 24 hours in apparatus[2]	19.0–20.5	18.0–20.0	102–111	1.80–2.40	2.10	4	3	3
18/10/55	5/10/55	22 hours in apparatus[2]	18.0–20.5	19.5–20.0	102–111	1.98–2.60	2.23	3	1	1
25/10/55	21/10/55	18 hours in apparatus[2]	17.0–20.0	19.8–20.5	108–111	1.96–3.00	2.70	5	4	3
10/10/55	5/10/55	18 hours in apparatus[2]	11.0–20.5	18.5–21.0	95–124	2.28–3.28	2.72	5	4	4
1/11/55	21/10/55	20 hours in apparatus[2]	18.5–20.0	20.5–21.0	111–114	2.70–3.40	2.96	3	3	3
5/10/55	5/10/55	17 hours in apparatus[2]	16.0–20.5	19.5–21.0	90–100	2.96–3.40	3.04	5	5	5

[1] Water temperature in apparatus decreased during holding period from about 20° C. to first value in next column.
[2] CT = Time in constant temperature room at 20° C.
[3] Test made at a current velocity of 1.2 feet per second. It may be assumed that all the fish would have resisted a current of 0.8 foot per second also.

he holding tanks approximated those main-ained in the experimental apparatus, the fish vere transferred directly from the stock tanks o the apparatus. At other times of the year, he fish were first brought into a constant tem-)erature room in order to acclimatize them to he experimental temperatures. Fish usually vere introduced into the apparatus the day be-ore testing. All experiments except those with ass were performed at approximately 20° C. During the summer months, bass were tested at 25° C. Later in the year, they were tested at ower temperatures, because of inadequate apacity of the immersion heater used in the ilot model. A temperature history of the ex-eriments with chinook and coho salmon is ncluded in Tables 1 and 2. The length of time sh were acclimated in the constant tempera-ure room or the apparatus before the experi-ent was started is given. The temperature hanges in the apparatus from the time the fish ere introduced until they were brought to the esired current velocity are also recorded, as re also the temperatures in the apparatus dur-ing the remainder of the experimental period. It may be noted (Table 2) that the temperature in a few cases fell considerably during the period from the introduction of the fish into the tube to the next morning when the pump was turned on to begin the experiment. There was no evidence that the performance of the fish was adversely affected by these temperature fluctuations.

The salmonids were fed at least every other day with a food mixture consisting of marine fish, liver, and horsemeat. They fed readily and grew in length in the holding tanks. Bass were fed live minnows and earthworms.

Three to seven fish were introduced into the apparatus through the glass funnel at the top of the tube near one end and were removed at the conclusion of the experiment through the opening below the funnel (Figure 1). The fish were not fed after being placed in the apparatus. The current was brought up by increments to the test velocities of 0.8 and 1.2 feet per second in the course of 2 and 3½ hours, respectively. The current increments were made

ABLE 2.—*The ability of juvenile coho salmon to swim against a current of 0.8 per second in water of reduced oxygen content for one and two days* [Fish were from the Alsea Trout Hatchery]

Date of experiment	Date fish collected	Acclimation history	Temperature range before oxygen reduction (°C.)	Temperature range during experiment (°C.)	Total length of fish (millimeters)	Dissolved oxygen (milligrams/liter)		Number of fish used	Number of fish swimming after one day
						Range	Mean		
				(*Fish from McKenzie River Salmon Hatchery*)					
27/5/56	29/3/56	24 hours in apparatus[1]	15.0–19.5	19.0–20.5	64–70	2.1–2.8	2.53	5	2
21/2/57	2/2/57	9 days, CT[2]	18.5–20.0	19.0–20.0	108–114	2.3–2.7	2.56	3	2
1/5/56	29/3/56	15 hours in apparatus[1]	17.0–20.0	19.5–22.0	54	2.4–3.2	2.72	4	1
19/6/56	1/6/56	17 hours in apparatus[1]	20.0–21.0	19.0–23.0	57–64	2.8–3.0	2.84	4	4
5/3/57	8/2/57	3 days, CT[2]	19.0–20.0	20.0–20.5	103–114	2.7–3.2	2.90	3	1
6/7/56	1/6/56	No acclim.	17.0–20.0	21.0–23.5	67–73	2.7–3.2	2.90	6	6
7/3/57	8/2/57	5 days, CT[2]	20.0–20.5	20.0–20.5	121	2.8–3.1	2.99	3	3
9/2/57	8/2/57	7 days, CT[2]	18.0–18.5	19.5–20.0	102–121	3.0–3.1	3.08	4	4
5/5/56	29/2/56	16 hours in apparatus[1]	15.0–20.5	18.5–22.5	57–64	2.7–3.4	3.11	7	4
				(*Fish captured in Willamette River*)					
3/6/55	10/5/55	24 hours in apparatus[1]	18.0–20.0	19.7–21.0	64–70	3.00–3.10	3.03	6	6
3/6/55	10/5/55	16 hours in apparatus[1]	18.0–20.5	19.0–21.5	64–73	3.30–3.56	3.47	6	6[3]
9/6/55	10/5/55	20 hours in apparatus[1]	18.5–21.0	18.5–21.5	64–83	3.44–3.64	3.52	6	6[3]

[1] All fish transferred from holding water which varied between 1.0° and 16.° C.
[2] Water temperature in apparatus decreased during holding period from 20° C. to first value in next column.
[3] CT = Time in constant temperature room at 20° C.
The mean value for dissolved oxgen content is for the first day of the experiment. In no case did the two-day mean differ from the one-day value by more tn .1 milligram per liter.

at half-hour intervals. After the desired current velocity was reached, the dissolved oxygen concentration of the inflowing water was gradually reduced to the desired level by increasing the flow of nitrogen gas. Analyses of the water were made periodically during the adjustment period and during the course of the experiment by use of the azide modification of the Winkler method, and appropriate adjustments of nitrogen flow were made when necessary. About four hours were required to reduce the oxygen concentration to the lowest oxygen levels tested. Fish were subjected to the final test conditions for periods of one or two days.

RESULTS

Chinook salmon

The ability of juvenile chinook salmon to swim against currents of 0.8 and 1.2 feet per second (ft./sec.) was in part dependent on their size. Only when juvenile chinooks over 50 mm. in total length were used were all of them found to be able to swim for one or two days against a current of 1.2 ft./sec. in water with dissolved oxygen near the air-saturation value. When fish below 50 mm. in total length were used, some could not resist this current for this length of time as is demonstrated by experiments performed in May, 1955. In these tests only three of five fish of 40 to 50 mm. in total length were able to swim for a day at a velocity of 1.2 ft./sec. On the other hand, all fish measuring from 60 to 66 mm. were able to swim against this current for a day. Even at a velocity of 0.8 ft./sec. in water with dissolved oxygen near the saturation value many of the fingerlings below 50 mm. in total length failed to swim for the test period. On the other hand, in no case did chinooks measuring more than 60 mm. fail to swim at a velocity of 0.8 ft./sec. for one or even two days in air-saturated water. It may be noted in this connection that Kerr (1953) found that juvenile chinooks measuring less than 2 inches (50.8 mm.) could swim against a current having a velocity of 0.9 ft./sec. for 10 minutes, but could not swim for this period against a current of 1.7 ft./sec.

The ability of juvenile chinook salmon to swim against a current of 0.8 ft./sec. is in part dependent also on the concentration of dissolved oxygen (Table 1). In experiments in which the water had a mean dissolved oxygen concentration of 2.99 milligrams per liter (mg./l.) or greater, in all experiments but one, fish were able to swim for at least one day against a current of 0.8 ft./sec. In all tests at mean oxygen concentrations less than 2.84 mg./l., some fish were unable to swim for one day. Between mean dissolved oxygen concentrations of 2.84 and 3.11 mg./l., there was variation in the performance of the fish.

Juvenile chinook salmon require somewhat higher concentrations of dissolved oxygen to be able to swim for one day against a current velocity of 0.8 ft./sec. than they require for survival for the same period when at rest. In Figure 2, curves A and B show the percentage of survival of quiescent juvenile chinooks for one day at 20° C. plotted against the concentration of dissolved oxygen. Data for these curves were obtained from experiments conducted in 1953 and 1957 using an apparatus in which the fish were held in bottles continuously receiving water of controlled temperature and oxygen content. Curve C shows the relation between oxygen concentration and the percentage of chinooks able to swim continuously for one day. All curves were fitted by inspection.

Coho salmon

In experiments at mean dissolved oxygen concentrations of 2.96 mg./l., or above, all of the juvenile coho salmon were able to swim against a current of 0.8 ft./sec. for two days (Table 2 and Figure 3). At oxygen levels between 2.03 mg./l. and 2.72 mg./l. some of the juvenile cohos were able to swim for one or two days.

As was shown for chinooks, a somewhat higher concentration of dissolved oxygen is necessary for coho salmon to swim against a current of 0.8 ft./sec. for one or two days at 20° C. than is necessary for the survival of these fish in a resting state for the same periods of time at the same temperature. Curves A and B, shown in Figure 3, have been fitted by inspection to points based on data from experiments performed by others (Davison, 1954; McNeil, 1956) in 1953 and 1954 on the survival of coho salmon in a resting state. While the results of the 1953 and 1954 experiments with resting fish show striking differences, Curve C (Figure 3) fitted to data for swimming fish definitely indicates that a higher concentration is necessary for the fish to maintain themselves in the current.

Largemouth bass

In one experiment with largemouth bass performed in September, 1956, all of the fish were able to swim against a current of 0.8 ft./sec. for one day at 25° C. in water having a mean dissolved oxygen concentration of 2.05 mg./l. In a second experiment, some fish were able to swim for one day at a mean dissolved oxygen concentration of 1.61 mg./l. In late October, at 20° C., no bass were able to swim by the time the oxygen concentration was reduced to 2.8 mg./l. In early December, at temperatures of 15.5 to 17° C., though the bass could swim against the 0.8 ft./sec. current when the water was nearly saturated with dissolved oxygen, they were unable to do so by the time the oxygen was reduced to 5.0 mg/l.

DISCUSSION

This study has shown that juvenile chinook and coho salmon are able to swim continuously against a current of 0.8 ft./sec. for one day

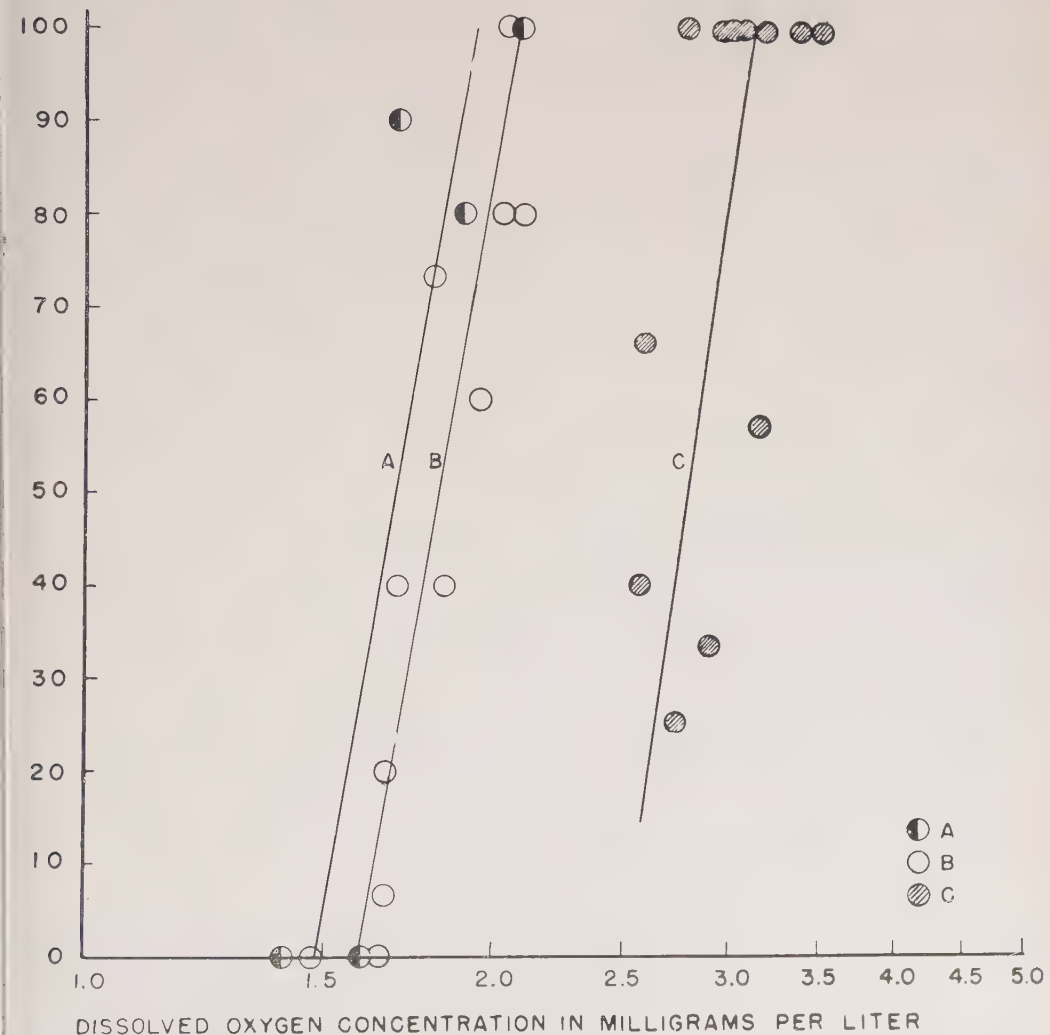

FIGURE 2. The survival for one day of resting juvenile chinook salmon and their ability to swim for one against a current of 0.8 foot per second, in relation to the dissolved oxygen concentration. A. Experiments on survival of resting fish performed in the summer of 1953. B. Experiments on survival of resting performed in the spring of 1957. C. Experiments on ability to swim, performed in 1956 and 1957.

at oxygen concentrations only slightly higher (by about 1.0 mg./l.), than those necessary for survival of quiescent fish for the same period of time. These results suggest a rather high degree of respiratory efficiency. Graham (1949) has shown that both the active metabolic rate and cruising speed of speckled trout, *Salvelinus fontinalis,* (measured on fish swimming against a current in a rotating chamber) fall off at dissolved oxygen concentrations substantially above the oxygen concentration at which the metabolic rate of quiescent fish begins to decline. Gibson and Fry (1954) obtained similar results in studying the active metabolic rate of the lake trout, *Salvelinus namaycush.* In view of these results, it is interesting to find juvenile chinook and coho salmon capable of a high level of performance at oxygen concentrations close to the minimum tolerable level.

Marked seasonal changes in the ability of largemouth bass to swim at reduced oxygen concentrations seemed to occur between September and December. This decline in performance may have been due largely to seasonal changes in activity associated with falling

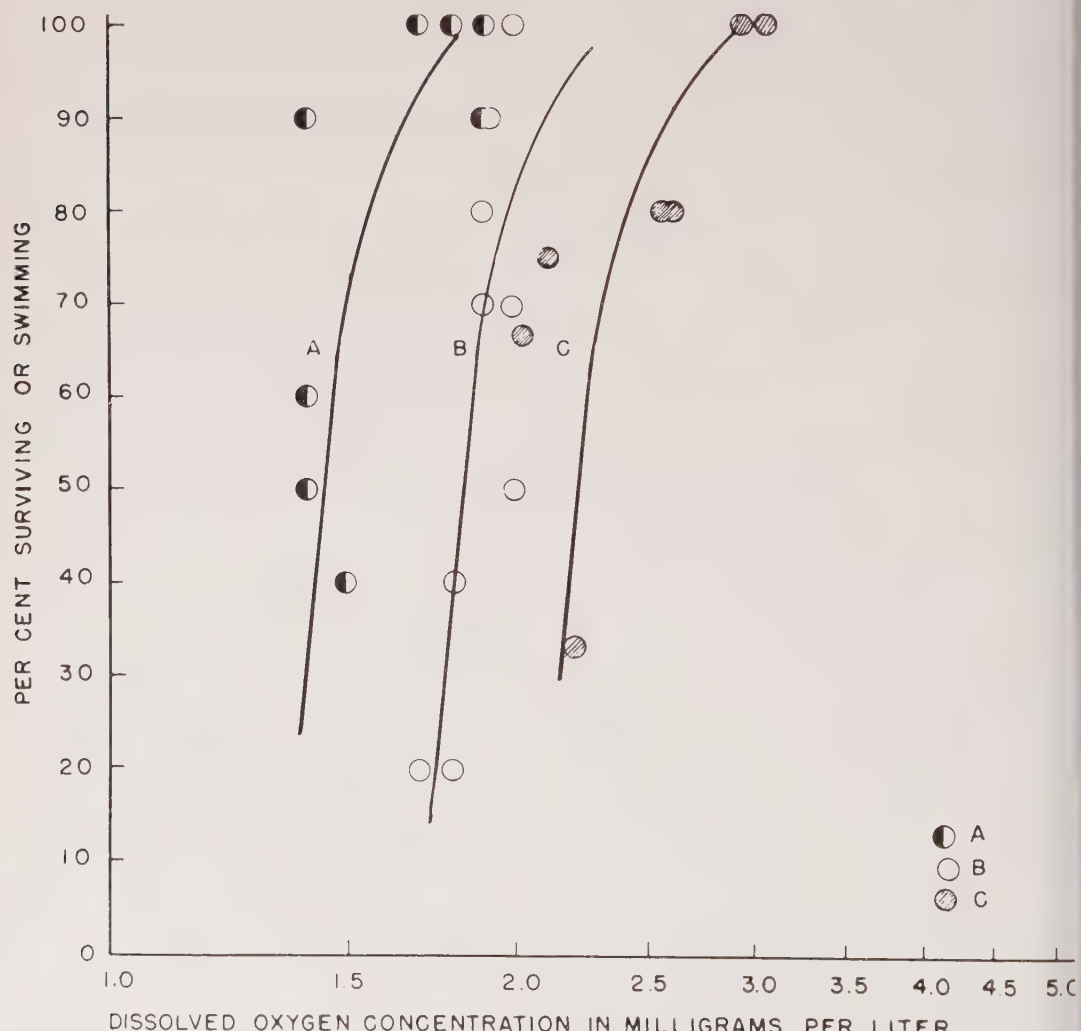

FIGURE 3. -The survival for one day of resting juvenile coho salmon and their ability to swim for one day against a current of 0.8 foot per second, in relation to the dissolved oxygen concentration. A. Experiments on survival of resting fish performed in the fall of 1953 (Davison, 1954). B. Experiments on survival of resting fish performed in the summer of 1955 (McNeil, 1956). C. Experiments on ability to swim, performed in the fall of 1955.

temperatures of the water from which the bass were taken. However, the unavoidable lower experimental temperatures in late October and December probably were at least partly responsible.

Studies of the kind reported here indicate dissolved oxygen concentrations at which the fish may lose the ability to swim against moderate currents for extended periods of time. However, the ecological significance of such a loss of swimming ability is unknown. It is improbable that juvenile salmon or bass in nature would ordinarily be required to swim continuously against currents such as these for one or two days. Yet, momentarily, they might be required to resist currents of much higher velocity. More must be learned of the swimming requirements of young fish in nature before laboratory experiments can be designed which will clarify the possible influence of dissolved oxygen on the ability of fish to maintain normal activity in a natural environment.

Results such as these, taken alone, cannot be indicative of minimum standards for dissolved oxygen concentrations in waters receiving wastes. Conditions adequate only for the survival or even the swimming requirements of fish may not insure high productivity levels of valuable populations. Conditions must also be adequate for the reproduction, development, growth, and unhampered activity of the individuals of the populations. Some published data of others, as well as certain unpublished data from investigations of this laboratory, indicate that substantially higher concentrations of dissolved oxygen are necessary for satisfactory development and growth of salmonids.

ACKNOWLEDGEMENTS

Mr. Orval Greer, Superintendent of the McKenzie Salmon Hatchery of the Oregon Fish Commission, supplied young chinook fingerlings for some of the experiments. Mr. Glaucus Webb and Mr. Paul Vroman, past and present superintendents, respectively, of the Alsea Hatchery of the Oregon Game Commission, supplied the coho fingerlings. Mr. Charles D. Woods of Research Products, Corvallis, and Dr. Peter Doudoroff of the U. S. Public Health Service helped with the development of the experimental apparatus. Dr. Doudoroff participated in the planning of the study. Professor R. E. Dimick, Head of the Department of Fish and Game Management, Oregon State College, facilitated the work.

LITERATURE CITED

DAVISON, ROBERT CHALMERS. 1954. Some effects of low concentrations of dissolved oxygen upon juvenile silver salmon. Master of Science thesis, Oregon State College Library, Corvallis, Oregon, 48 typed pages.

FRY, F. E. J. AND J. S. HART. 1948. Cruising speed of goldfish in relation to water temperature. Jour. Fish. Res. Bd., Canada, Vol. 7, (4), pp. 169-175.

GIBSON, E. S. AND F. E. J. FRY. 1954. The performance of the lake trout, *Salvelinus namaycush*, at various levels of temperature and oxygen pressure. Canadian Jour. Zool., Vol. 132, pp. 252-260.

GRAHAM, J. M. 1949. Some effects of temperature and oxygen pressure on the metabolism and activity of the speckled trout, *Salvelinus fontinalis*. Canadian Jour. of Research, D, Vol. 27, pp. 270-288.

GRAY, J. 1957. How fishes swim. Scientific American, Vol. 197, (2), pp. 48-65.

JOB, S. V. 1955. The oxygen consumption of *Salvelinus fontinalis*. Univ. of Toronto Biol. Series, No. 61. Publ. of the Ontario Fish. Res. Lab., No. LXXIII, 39 p.

KERR, JAMES E. 1953. Studies on fish preservation at the Contra Costa steam plant of the Pacific Gas and Electric Company. Fish. Bull. No. 92, State of California Dept. of Fish and Game, 66 p.

MCNEIL, WILLIAM JOHN. 1956. The influence of carbon dioxide and pH on the dissolved oxygen requirements of some fresh-water fish. Master of Science thesis, Oregon State College Library, Corvallis, Oregon, 82 typed pages.

Studies on the Life Cycle of Apatemon gracilis pellucidus (Yamag.)

[Trematoda: Strigeoidea]

GLENN L. HOFFMAN

Bureau of Sport Fisheries and Wildlife, Eastern Fish Disease Laboratory
Leetown (P.O. Kearneysville), W. Va.

ABSTRACT

A tetracotyliform metacercaria was found in the musculature of the brook stickleback (*Eucalia inconstans*). It is characterized by a tail-like appendage on the cyst. The adult was reared in newly hatched chicks, and proved to be *Apatemon gracilis pellucidus* (Yamaguti, 1933). Attempts to infect snails, *Physa, Stagnicola* and *Helisoma,* were unsuccessful.

During the summer of 1954, a tetracotyliform metacercaria was found encysted in the musculature of brook stickelback (*Eucalia inconstans*) collected from the English Coulee, Grand Forks, North Dakota. Cysts force-fed to newly hatched chicks developed into ovigerous adult worms in the intestine in three days. The chicks were fed a small amount of commercial fox chow.

Apatemon pellucidus, metacercaria and adult, was described by Yamaguti (1933) from Japan who found the metacercaria (*Tetracotyle*) encysted in the body cavity of the fish, *Mogurnda obscura* (Eleotridae). He developed the adult, experimentally, in domestic ducklings. Dubois (1953) considers this worm to be a subspecies, naming it *Apatemon gracilis pellucidus* (Yam.). The other subspecies are *A. g. gracilis* and *A. g. fuligulae* known from mergansers and wild ducks respectively. The present account is the first record of *A. g. pellucidus* from North America.

MATERIALS AND METHODS

As many stickleback as could be collected were ground up with a small food chopper and digested with approximately 20 milliliters of digest fluid to 1 gram of fish. The digest fluid consisted of one-half percent pepsin N. F. in one-half percent hydrochloric acid. The jars were placed in a water bath shaker at 39° C. for one to two hours after which the cysts were allowed to settle to the bottom (about 15 minutes), and the supernatant decanted. The resulting concentration of cysts was force fed with a small diameter dropper to newly hatched chicks.

The adult worms were recovered from th chicks by slitting open the intestine, shakin the contents into saline solution, and recove ing the worms from the sediment. The washe intestine was also examined for the presen of remaining parasites.

Metacercariae and adults were examine alive, and fixed in hot Bouin's fixative a stained with Harris' hematoxylin.

Sections of muscle containing cysts we stained with Mallory's triple connective tiss stain as well as hematoxylin and eosin.

THE METACERCARIA

The cysts were first found in the stoma contents of a bittern (*Botaurus lentiginosus* but no adults were present in the intestin Artificial digest of 126 stickleback fish fro the same area yielded an average of 3.2 cy per fish. A year later 30 stickleback from t same stream were digested but yielded on one *Tetracotyle,* and none were found in t fish examined the following year.

It was very difficult to free the metacercari from their cysts mechanically, but a quick pe sin digest (½-1 hr) followed by 10-15 mi utes in trypsin digest (0.1 percent trypsin 1.0% $NaHCO_3$) at 38-39° C. resulted nearly all larvae becoming excysted. Mov ments of the excysted larvae were comparati ly sluggish. The following measurements a all in microns.

The Cyst. The complete cyst is oval, *ca.* 10 by 600, and almost always with a yellowi tail-like structure, *ca.* 400 by 100, on one en this projection is always directed anteriorly posteriorly in the musculature of the fish. histological cross section the host cyst is co posed of two parts, an outer cellular (loc

connective tissue) layer, *ca.* 15 thick, and an inner, thicker layer composed of transparent, hyaline connective tissue 48-97 thick. The projection is also composed of hyaline connective tissue but is less dense. The cyst of parasite origin is slightly pear-shaped, opaque white, measures *ca.* 515 by 452 and its wall is *ca.* 8 thick. There is no apparent histopathology except the structure of the cyst itself.

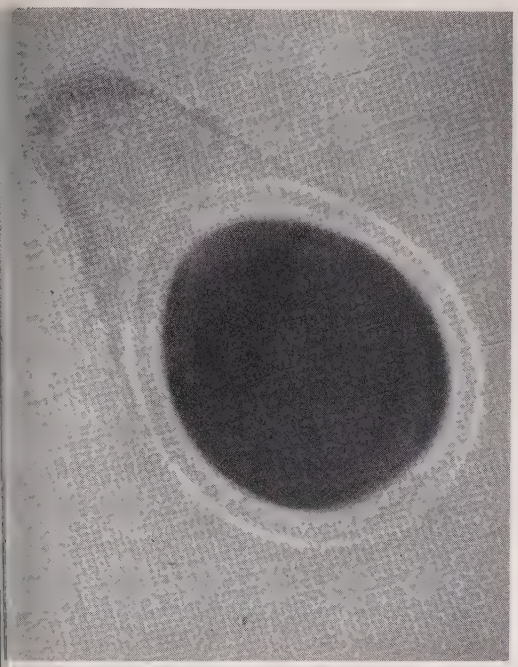

FIGURE 1. Photomicrograph of the cyst of *Apatemon gracilis pellucidus* showing the rigid hyaline cyst and "tail" of looser connective tissue.

The Tetracotyle. Alive, the metacercaria is . 564 by 360 and is divided into two regions; e forebody, somewhat oval shaped and deeply upped" is *ca.* 417 long; the hindbody is untly conical. The oral sucker is terminal tt may appear subterminal when the anterior d is curled under and is *ca.* 82 in diameter. ne pharynx and ventral sucker are not easily ible when alive but measured 47 by 92 and by 100, respectively, in two specimens fixed hot Bouin's. The ventral sucker is approxitely midway in the worm. The holdfast nsists of a small inner lobe and a larger ter lobe which usually extends to the anterior rgin of the ventral sucker, but in some cimens it extends further and it is *ca.* 146 diameter. The holdfast gland, located at the terior of the holdfast is *ca.* 31 long by 65 le. The esophagus is *ca.* 9 long. The caeca extend to the posterior of the hindbody and are 14 microns in diameter anteriorly and 21 posteriorly. The lateral pseudosuckers are lateral to the oral sucker near the anterior, lateral edge of the lip of the "cup" and are *ca.* 75 by 37.

The excretory system was not studied in detail and is a very complicated network of channels which gives the forebody an "accordion" appearance. The excretory bladder in the hindbody is composed of two broad tubes which unite at the posterior extremity to form the excretory pore. The reproductive primordium, *ca.* 82 by 85, is located centrally in the hindbody.

Fixed and stained, measurements in microns of seven specimens fixed in hot Bouin's were: body 547 (452-739) by 307 (221-379), forebody 345 (307-403), hindbody 154 (115-192) by 173 (163-172), oral sucker 67 (52-80), pharynx 42 (37-50) by 35 (25-45), esophagus 37, lateral suckers 82 (75-87) by 52 (50-57), ventral sucker 82 (75-87) by 110 (110-112), holdfast 135 (125-137) by 152 (125-182), holdfast gland 35 (34-37) by 110 (105-112), reproductive primordium 87 (80-100) by 77 (75-80).

THE ADULT

Eight chicks were given 9-150 metacercariae each, and from these, 0-35 ovigerous adults were recovered from the upper one third of the small intestine in 3-12 days. This is a mean recovery of 18.3 percent. The adults appeared normal in all respects.

Live measurements in millimeters of four worms, depending upon their state of expansion and contraction, were 1.5 to 1.8 in length by 0.45 to 0.54 in greatest width. The body is divided very distinctly into two parts, the hindbody being the larger—0.9 to 1.05 in length. The forebody is very deeply cupped. The ventral lip almost reaches the oral sucker, and the large holdfast organ can be extended, tongue-like, through its opening. Usually the outer lobe, which is larger, has the greatest forward extension, but occasionally this is true of the inner lobe. Lateral pseudosuckers are not apparent. The caeca are distended posteriorly, and can be seen easily because of their yellow contents. There are about 15 eggs in utero; 10 measured 0.101 (0.08 to 0.115) by 0.058 (0.05 to 0.06).

When fixed in hot Bouin's solution and stained six worms measured 1.52 (1.26 to 2.07) millimeters in length by 0.47 (0.39 to

0.57) in greatest width. Forebody is deeply cupped and entire worm is flexed dorsally. Other measurements in millimeters are: Forebody 0.566 (0.527 to 0.702) by 0.468 (0.390 to 0.566); hindbody 1.053 (0.819 to 1.395) by 0.507 (0.429 to 0.566); oral sucker 0.115 (0.106 to 0.125) in diameter; no prepharynx; pharynx 0.086 (0.067 to 0.115) by O.077; ventral sucker 0.134 (0.115 to 0.154) by 0.154 (0.134 to 0.173). The holdfast consists of two parts, an inner lobe and an outer lobe—the latter is more often extended forward to the lip of the "cup"; entire holdfast 0.365 (0.334 to 0.480) by 0.240 (0.192 to 0.288); holdfast gland 0.106 (0.048 to 0.144) by 0.154 (0.125 to 0.182); ovary nearly round 0.125 (0.115 to 0.154) by 0.125 to 0.133); first testis 0.230 (0.173 to 0.268) by 0.230 (0.192 to 0.269); second testis 0.250 (0.192 to 0.307) by 0.250 (0.240 to 0.269). Size proportions are: hindbody/forebody 1.53; anterior margin of first testis=23 percent of hindbody; posterior border of second testis=73 percent of hindbody; oral sucker/pharynx=1.3.

The vitelline follicles extend from the anterior of the hindbody to just ahead of the bursa copulatrix and from the ventral surface to one-fourth to one-third the width of the worm. In some specimens a few follicles can be seen extending into the forebody.

In an attempt to establish the first intermediate host laboratory reared snails (77 *Physa anatina,* 68 *Stagnicola palustris,* 7 *Helisoma anceps*) were exposed to the miracidia of the experimentally raised flukes; all were negative upon dissection in 11 to 40 days.

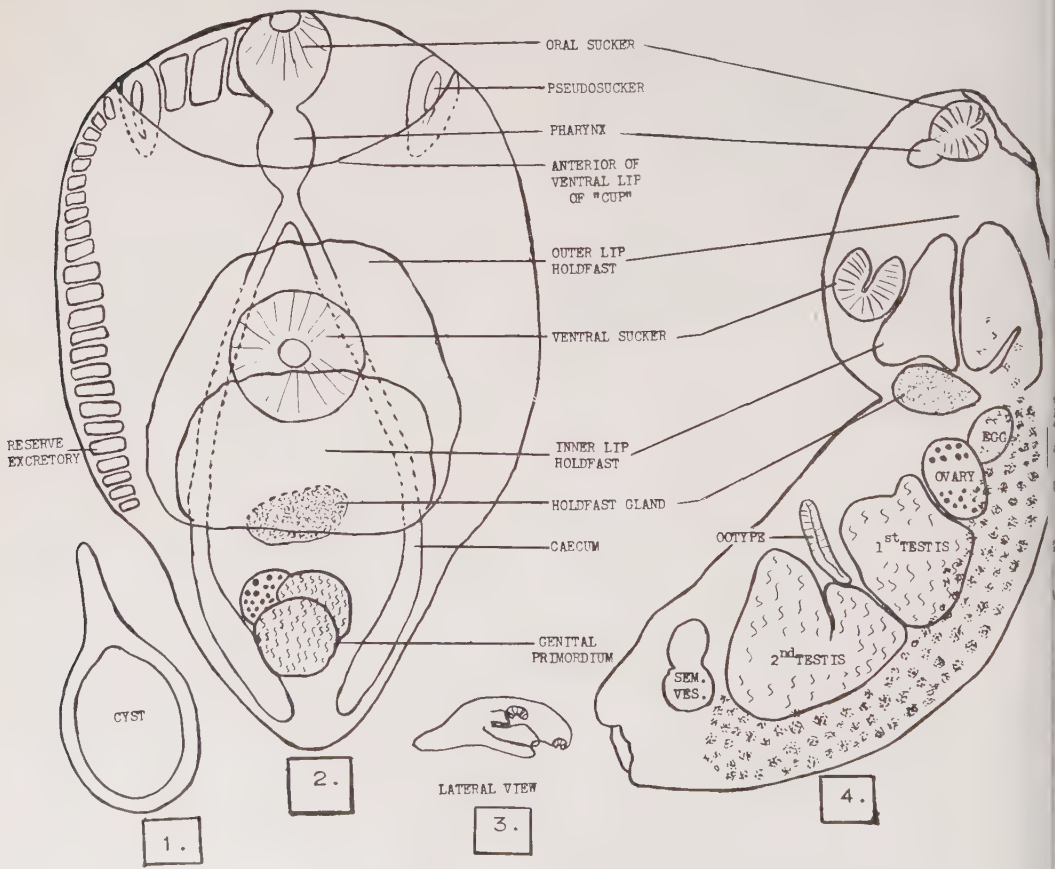

FIGURE 2.—Cyst, tetracotyle and adult of *Apatemon gracilis pellucida.* 1. Complete cyst; freehand sketch. 2. Ventral view of tetracotyle; composite drawing. 3. Lateral view of tetracotyle showing usual position of inner and outer lips of the holdfast organ; freehand sketch. 4. Lateral view of adult; drawn with aid of microprojection. Drawings are not to the same scale.

DISCUSSION

No distinct morphological difference could be found between the North Dakota specimens and the description of *Apatemon pellucidus* (Yam.) except that Yamaguti illustrates his worm with the vitellaria extending dorsally about ¾ of the way across the hindbody whereas the present writer's specimens demonstrate vitellaria extending dorsally only ¼ to one-third across the hindbody; this may, or may not, be a real difference. Also, in the present material a few follicles, interpreted as vitelline follicles, were seen extending into the forebody of some specimens. If these are vitelline follicles this is unusual because according to Dubois (1953), the genus *Apatemon* does not possess forebody vitellaria. The adult has been studied only from experimental material and the natural definitive host is unknown.

ACKNOWLEDGEMENTS

The writer wishes to thank Dr. George Dubois, Neuchatel, Switzerland for identifying the experimental adult worm and kindly giving advice on the taxonomy involved, Mr. James Hundley, North Dakota Public Health Department for technical assistance, and Drs. S. F. Snieszko and Ken Wolf for proofreading the manuscript.

LITERATURE CITED

Yamaguti, S. 1933. Studies on the helminth fauna of Japan. Part 1. Trematodes of birds, reptiles and mammals. Japan. J. Zool. Vol. 5(1), pp. 1-134.

Dubois, G. 1953. Systematique des Strigeida. Complémen de la monographie. Mém. Soc. Neuchatel. Sc. Nat. Vol. 8(2), 141 pp.

Biological and Economic Aspects of the Management of Commercial Marine Fisheries

Milner B. Schaefer
Inter-American Tropical Tuna Commission, La Jolla, California

ABSTRACT

Conservation management of the commercial marine fisheries has the general objective of maximizing man's long-term benefits from the exploitation of the fish resources. The question of what is most beneficial to man involves both biological and economic considerations. In this paper some of the effects of fishing on the fish stocks, and on the sustainable yields from them, are considered, together with important economic factors. It is indicated that the maximum sustainable average catch and the maximum net economic yield are mutually exclusive. It is possible, however, to obtain *some* net economic yield at the level of maximum sustainable harvest, but this requires some modification of the common property nature of fish stocks.

Conservation of the marine fisheries resources is a subject of interest to a great many members of this Society, and is a matter with which governmental agencies of the United States and various international agencies are much concerned. Conservation, in the modern sense, does not mean simply the preservation of a resource for the future, but also encompasses its use for man's benefit both in present and future time. It has often been said that "conservation is wise use." It may also be fairly stated that the objective of conservation management of commercial marine fisheries is to maximize man's long-term, continuing benefits from the exploitation of the fish resources. It is by no means clear, however, just what degree and kind of exploitation constitutes wisdom, nor which among possible alternatives is most beneficial.

I am certainly not going to attempt to answer these questions. But I think that it will be worthwhile to consider some of the fundamental biological properties of fish populations, and some of the principles of the economics of their harvesting, which should be taken into account in reaching the answers.

SOME BIOLOGICAL ASPECTS

Populations of marine fishes, in common with other living resources, differ from nonliving resources in an important respect; they are continuously renewed, and the rate of renewal depends on the size of the population which is left unharvested to produce new generations. A second important characteristic is that such populations tend to remain in dynamic balance, neither falling to zero nor increasing without limit. Over any reasonably long period of time, losses from the population must be balanced by accessions to the population. For a wide range of population sizes, when the percentage rate of loss is increased, decreasing the size of the population, from whatever cause, the percentage rate of renewal also increases, so that the population again comes into balance. This, of course, is the biological basis of fisheries, because from the standpoint of the fish the harvest taken by man is simply an additional source of mortality by predation, which is met by a compensatory increase in rate of population renewal, so that the population again comes into balance at some lower level of abundance at which increased rate of population growth balances the harvest taken by man. This must be so, else *any* continuing fishery would drive the population out of existence.

It may thus be seen that over a wide range of population sizes, and a correspondingly wide range of fishing effort, the population will come into dynamic balance, and a continuing harvest may be maintained. Although it is, theoretically, possible to impose such a large rate of predation on a fish population as to drive it below the level at which the self-regulating mechanism can bring it again into dynamic balance, to drive it below its threshhold level for survival, for commercial marine fisheries this is almost always below the level at which it is economically possible to fish. We are not often, therefore, concerned with preventing a commercial fish population from being exterminated. The problem is, rather, from among the range of fishing effort, be-

tween zero and the maximum that is economically possible, to determine that which is optimal.

The general form of the relationship among amount of fishing, steady-state average population size, and magnitude of average sustainable catch, is known from the results of theoretical and experimental studies both of fishes and of other organisms, e.g. Nicholson (1954a, b), Ricker (1954), Lack (1954), and Silliman and Gutsill (1957), and from the data of important commercial fisheries (Buckmann 1938; Graham 1935, 1939; Schaefer 1954, 1957b; Beverton and Holt 1957, etc.), and may be illustrated as in Figure 1. With no fishing, the virgin population of fish of commercial sizes fluctuates about some size, L, which is the maximum which the environment will support under average conditions; there is no harvest. With the application of a little fishing effort, the population will come into balance at a magnitude somewhat below the virgin level, there will be a small harvest and the catch-per-unit-of-effort (which is proportional to population size) will be high. As the fishing effort increases, the steady-state population size decreases continuously, while the sustainable catch increases, but at a continually decreasing rate. At some intermediate level of fishing effort (labelled E_m on the Figure) there will be reached a maximum of sustainable total catch, after which the harvest actually decreases with increasing effort.

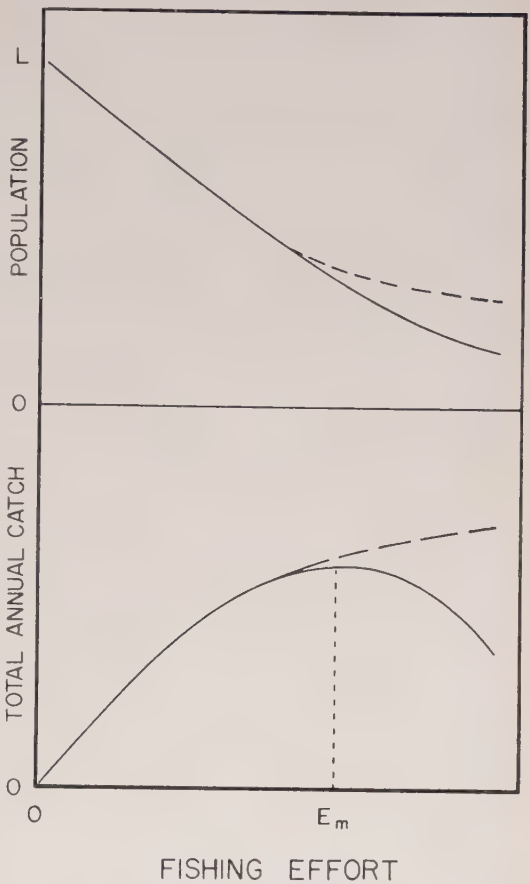

FIGURE 1.—General form of the relationship among amount of fishing, steady-state average population size, and magnitude of average sustained catch in a commercial fishery.

It should be noted that these are average relationships. Superimposed are fluctuations due to variations in fishery-independent (environmental) factors. These variations are often so large that it is difficult to estimate for particular fisheries the fishery-dependent relationships, and there are also important, short-term fishery management problems because of such variations.

It is biologically possible to have a sustained fishery at any of a wide range of fishing efforts. The problem is to decide which of these is most desirable. One possible choice is the level of maximum sustainable yield, E_m on the graph, at which the greatest poundage will be produced, on the average, in perpetuity. This has been explicitly chosen for particular fisheries (e.g. North Pacific halibut, tropical tuna) and has recently been adopted as a general objective by the International Conference on the Law of the Sea. Article 2 of the Convention on Fishing and Conservation of the Living Resources of the High Seas, adopted at that Conference, says, "As employed in this Convention, the expression 'Conservation of the living resources of the high seas' means the aggregate of the measures rendering possible the optimum sustainable yield from those resources so as to secure a maximum supply of food and other marine products." This choice is, however, not universal, because it is sometimes desired to take into account other qualities of the fishery.

Graham (1956) and Beverton and Holt (1957) have pointed out that it may be desirable to take into account the average size of the fish (which, in general, declines with increasing effort) and of other economic factors. The latter authors (p. 137 *et seq.*) also believe that if a fishery is managed by simultaneously controlling intensity of fishing and mini-

mum size of fish to provide the greatest catch, so-called eumetric fishing, the curve of sustainable catch on effort has *no* maximum, but rises continuously toward an upper assymptote; this is illustrated by the broken line in Figure 1. If this be so, for fisheries which can be so managed, the choice of most desirable level of effort *must* be made on other (economic) grounds.

Even if the maximum sustainable average yield be chosen as the primary objective of fishery management, economic aspects of the fishery become important when it comes to the means by which the fishing effort shall be controlled. It is, therefore, important to consider some of the simple economic principles of commercial fishing.

SOME ECONOMIC ASPECTS

Fishermen are not fishing for fish, but for dollars. The amount of fishing is, therefore, largely determined by the value of the harvest and the cost of taking it. We need, then, to consider the nature of the relationships among fishing effort, value of catch, and cost of fishing effort.

The form of the value of catch as a function of fishing effort depends on the relationship between effort and quantity caught, illustrated in Figure 1, and, in addition, on the relationship between quantity and price. For most individual stocks of sea fish, the catch is a rather small share of the total production of all fish with which it competes in the market, and fish compete with other foods; consequently the price elasticity of demand is large, that is the price decreases little or not at all with increased landings. In these circumstances, the form of the production function (total value versus fishing effort) is similar to the relationship between effort and catch in pounds, and the maximum occurs at the same level of fishing effort (E_m), as has been shown by Schaefer (1957a). This is illustrated as the "value" curve in Figure 2. The value-per-unit-effort (or average return) falls off continuously with increasing effort as shown in the upper panel of the same Figure.

As to the cost of fishing, the unit costs are largely determined by the general economy, so that, to a good approximation, the cost-per-unit-effort is constant, and the total cost is proportional to the total effort. In Figure 2, I have drawn the cost-per-unit-effort lines in the up per panel, and the corresponding total cos lines in the lower panel, for three differer levels of cost (C_1, C_2, and C_3), the signif cance of which I will come to in a few mo ments.

Now, fisheries resources, unlike most natura resources, are usually common property, bein open to all comers on an equal footing. I consequence, so long as there is an opportun ty to obtain more return to a unit of effo than its cost (including the normal return o capital investment, and a normal entrepreneur fee) men will be attracted to the fishery, an it will tend to come to natural stability wher the total value of the harvest is equal to th cost of taking it, and the average return equal to the average cost. Thus, as has bee described in detail by various authors, inclu ing Gordon (1953, 1954), Schaefer (1957a) and MacKenzie (1958), for the commor

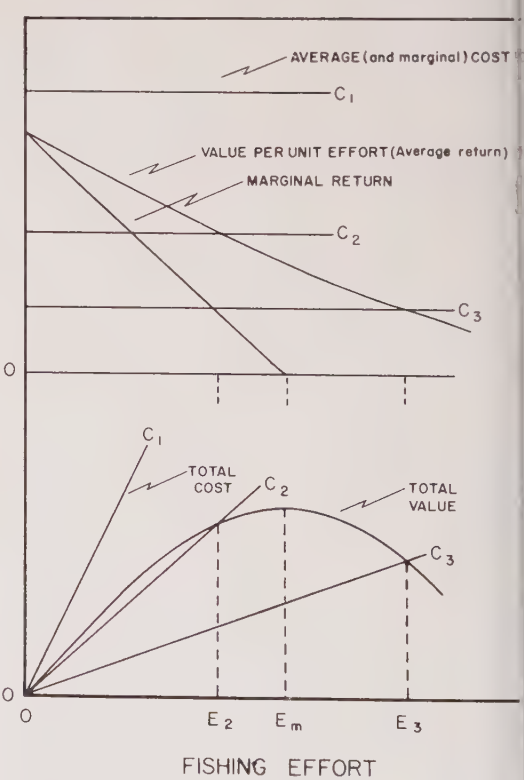

FIGURE 2.—Relationships among fishing effor total value of catch, and total cost for three differer levels of unit cost (lower panel); relationship among fishing effort, marginal and average return and marginal and average cost (upper panel). Se text for explanation.

roperty fish resource there can be no rental eturn to the resource, that is no net economic ield (the excess value of the harvest over ost of catching it).

The level of exploitation at which the unanaged fishery will reach stability depends n the value of catch relative to the cost of ffort. In Figure 2 are illustrated three possile situations, corresponding to an unutilized ish stock, an "underfished" fish stock and n "overfished" fish stock. In the first case, he cost of a unit of effort (C_1) is greater than he value-per-unit-of-effort, even at the virgin vel of stock abundance. Here the fish are ot worth catching. We know of many stocks this condition, for example the Pacific coast ake and saury stocks. In the second case, the st of a unit of effort (C_2) is such that it is qualled by the average return at a level of shing effort (E_2) below that corresponding maximum sustainable yield. Such a fishery "underfished" if the criterion is maximum stainable catch, and in this situation no reriction on fishing effort can produce a greatr average harvest than is being obtained. In he third case, the cost of fishing effort relave to the value of catch is such that the cost-er-unit-effort is equal to the average return at ievel of effort (E_3) *above* that corresponding maximum sustainable yield. Such a fishery commonly called "overfished," since the stainable yield can be increased by restricting shing effort.

It has been advocated by Gordon (1953, 954) that the fisheries should be managed produce maximum net economic yield, that the greatest difference between total cost nd total value of catch. This would be obined where the tangent to the production nction in terms of value is parallel to the st line, i.e. where the marginal return is equal the marginal cost. As shown in the upper nnel of Figure 2, this is always at a lower vel of effort than that which will be reached the unregulated common-property situation, nd is always at a lower level of effort and tch than that corresponding to maximum stainable yield. Thus, maximum sustainable ld and maximum net economic yield are utually exclusive. For "overfished" stocks is, however, possible to obtain *some* ecomic yield at the level of maximum sustainle catch, i.e. the difference between the cost ne, C_2, and the total value curve in the lower nnel of Figure 2, by restricting the effort to E_m, *providing that the regulations are such that they do not increase the fishing costs.*

IMPLICATIONS FOR FISHERIES MANAGEMENT

In the case of "overfished" stocks it is possible, as seen from the foregoing theory, and as has been demonstrated in practice in a number of marine fisheries, to increase the abundance of the fish and the total catch by restricting the fishing effort. If the effort were restricted in such a manner as not to increase the fishing costs, there could also be obtained some economic yield. Regulations in practice, however, such as overall catch-quotas, closed seasons, and legislation against efficient gear, which limit the effort while allowing free access to the fishery by all comers, result in the cost of effort being increased so that all the possible economic yield is dissipated. This, indeed, can only be overcome by managing the fishery as a unit enterprise and thus, in one way or another, establishing at least a limited property right in the resources.

If it is deemed desirable to maximize the net economic yield rather than the sustainable harvest, this, of course, requires that there be established property rights in the fishery, whether these rights be in private hands or belong to governments. It also implies some choice between production of fish and profit from the fishery, since, as has been shown, the level of maximum net economic yield is always at a lower level of harvest than the maximum sustainable catch, and than the harvest obtained in the underfished common-property fishery.

The establishment of property rights in marine fisheries presents very great difficulties, even for the inshore stocks under the sovereignty of a single nation. For the high-seas fish resources, fished jointly by several nations, the problems are even more formidable. In the case of a few inshore bottom-dwelling organisms, such as clams and oysters, it has been accomplished. In these cases it is possible to have many individual property owners. Property rights in the inhabitants of the waters, however, the unit stocks of which are commonly large and occur over extensive areas, would have to be of large magnitude, raising problems of monoply if privately owned, and of socialized business if government owned. Even more difficult is the problem of the international nature of the high-seas resources. Since there are rather notable differences in the economies of different nations, it would seem practically impossible to reach agreement on

the optimum level of fishing effort on economic grounds, and, even if that were possible, to decide the share of the fishery to be allocated to each nation. Beverton and Holt (1957, p. 395) are, however, apparently a bit more sanguine in the case of the North Sea at least. They say, "Here, in order to distribute equitably the benefits of regulation (to maintain the profit margin at a desirable level) among countries concerned, it is necessary only to agree on fixed ratios of fishing effort."

In any event, with the fuller utilization of the marine fisheries resources to meet the needs of the world's burgeoning population, it is certain that both the biological and the economic aspects of fisheries management will grow in importance, and that both aspects will need to be studied in detail as a guide to public policy with respect to these resources.

LITERATURE CITED

Beverton, R. J. H. and S. J. Holt. 1957. On the dynamics of exploited fish populations. U.K., Min. Agr. Fish and Food, Fish. Inv., Ser. 2, Vol. 19, pp. 1-533.

Bückmann, A. 1938. Ueber den Höchstertrag der Fischerei und die Gesetze organischen Wachstums. Ber. der Deutschen Wissenschaft. Komm. f. Meeresforschung, N.F., Vol. 9, pp. 16-48.

Gordon, H. S. 1953. An economic approach to the optimum utilization of fishery resources. Jour. Fish. Res. Bd. Canada, Vol. 10, No. 7, pp. 442-457.

———. 1954. The economic theory of a common property resource: the fishery. Jour. Political Economy, Vol. 62, No. 2, pp. 124-142.

Graham, M. 1935. Modern theory of exploiting fishery, and application to North Sea trawling Jour. Cons. Expl. Mer., Vol. 10, No. 3, pp 263-274.

———. 1939. The sigmoid curve and the overfishing problem. Rapp. et Proc.-Verb., Cons. Exp Mer., Vol. 110, pp. 15-20.

———. 1956. Concepts of conservation. Papers, In Tech. Conf. on Conservation of the Living Re sources of the Sea, pp. 1-13.

Lack, D. 1954. The natural regulation of anima numbers. Clarendon Press, Oxford, 343 pages.

MacKenzie, W. C. 1958. Some economic aspects c control by quota. Canad. Fish Culturist, No. 2 pp. 21-24.

Nicholson, A. J. 1954a. An outline of the dynami of animal populations. Austr. Jour. Zool., Vo 2, No. 1, pp. 9-65.

———. 1954b. Compensatory reactions of popul tions to stresses and their evolutionary signif cance. Austr. Jour. Zool., Vol. 2, No. 1, pp. 1-

Ricker, W. E. 1954. Stock and recruitment. Jou Fish. Res. Bd. Canada, Vol. 11, pp. 559-623.

Schaefer, M. B. 1954. Some aspects of the dynami of populations important to the management o the commercial marine fisheries. Bull., Inter-Ar Trop. Tuna Comm., Vol. L., No. 2, pp. 25-56.

———. 1957a. Some consideration of populatio dynamics and economics in relation to the ma agement of the commercial marine fisherie Jour. Fish. Res. Bd. Canada, Vol. 14, No. pp. 669-681.

———. 1957b. A study of the dynamics of th fishery for yellowfin tuna in the Eastern Tro ical Pacific Ocean. Bull., Inter-Am. Trop. Tu Comm., Vol. 2, No. 6, pp. 245-285.

Silliman, R. P. and J. S. Gutsill. 1957. Respon of laboratory fish populations to fishing rate Trans. Twenty-second North Am. Wildlife Con (1957), pp. 464-471.

Can We Manage Our Atlantic Coastal Fishery Resources?[1]

J. L. McHugh

Virginia Fisheries Laboratory, Gloucester Point, Virginia[2]

ABSTRACT

A fresh approach to coastal fisheries problems is needed; one including more biological and educational work and investigation of economic, social, and political factors which are potent influences in the interaction of fisheries resources and man. The conventional approach, by methods designed to foster management for optimum sustained yield for each important species, holds little promise for management of migratory fishes in inshore waters of the Atlantic coast. More consideration should be given to management of the biomass of the entire resource. Some statistics of the Atlantic coast fisheries are given and promising approaches for bettering management discussed.

INTRODUCTION

There has been a strong tendency in recent years to believe that simple application of the principles of population dynamics is all that is necessary to manage our fisheries. This implies that, once the necessary basic knowledge has been obtained, each species can be treated as an independent unit, as a biological entity to be investigated, and as a natural resource to be protected. The dynamics of certain fishery resources are sufficiently uncomplicated so that these principles can be applied with some success. The essential characteristics of such fisheries are that they be pursued by methods that exploit them more or less exclusively, and that other fisheries, directed principally at other species, do not take significant numbers of the species or population in question. Perhaps the best example of such a fishery, although the quarry is a mammal rather than a fish, is the fur-seal resource of the North Pacific, which has responded beautifully to experimental management methods. Another example is the halibut fishery of the North Pacific. The haddock fishery of the northwestern Atlantic also shows promise of management by rather simple manipulation of fishing effort in the form of mesh-size regulation, and prospects are bright for at least some segments of the Pacific salmon resource.

ATLANTIC COASTAL FISHERIES

Along the Atlantic coast of the United States there exist a number of fisheries that are not readily amenable to management by simple methods. They fail to meet two principal requirements: (1) that only one species is exploited; and (2) that each species is caught only by gear that seeks it exclusively. The principal species affected by these complications are fluke or flounder (*Paralichthys dentatus*), scup (*Stenotomus versicolor*), croaker (*Micropogon undulatus*), shad (*Alosa sapidissima*), striped bass (*Roccus saxatilis*), butterfish (*Poronotus triacanthus*), gray sea trout (*Cynoscion regalis*), alewife (*Alosa pseudoharengus*), and spot (*Leiostomus xanthurus*), and the principal commercial gears that catch them in quantity are pound nets, haul seines, and otter trawls (Table 1). In addition, unknown but certainly substantial quantities of scup, croaker, flounders, gray trout or weakfish, spot, shad, and striped bass are caught by sport fishermen on hook and line. For example, in Virginia the sport catch of croakers about equals the pound-net or the haul-seine catch, and in the Middle Atlantic region millions of pounds of scup and other species are taken by sport fishermen each year. In New Jersey, sport fishermen take about as great a weight of edible fishes as commercial operators (Younger and Zamos, 1955).

These fisheries interact almost inextricably with respect to species, time, and place, and their value is considerable (Table 2), somewhat over 12 million dollars landed commercial value, for the nine species listed above. Moreover, commercial gears capture large quantities of young, too small to be of great value for human consumption, yet valuable as industrial fish or as bait for crab pots and other gear. There is good reason to suspect that many of these young fish would yield a greater harvest in terms of commercial value, and perhaps also in weight, if they were allowed to grow for another 6 to 12 months, and many

[1] Contributions from the Virginia Fisheries Laboratory, No. 85.

[2] Present address: Chief, Division of Biological Research, Bureau of Commercial Fisheries, Washington 25, D. C.

TABLE 1.—*Landed value, in thousands of dollars, of the 1955 catch of some principal Atlantic coast inshore migratory fishes in the principal fishing gears*

[Plus sign (+) indiciates value less than 1]

Species	Pound net	Haul seine	Otter trawl	Gill net	Fyke net
Alewife	436	34	+	17	12
Bluefish	96	51	18	212	+
Butterfish	202	30	463	+	+
Croaker	305	512	298	66	1
Fluke	123	51	*3214	7	9
Gray sea trout	230	233	284	45	1
King whiting	5	53	203	18	—
Mullet	1	175	+	371	1
Scup	200	7	2035	1	+
Shad	486	70	+	843	15
Spot	68	426	30	89	2
Striped bass	135	316	10	590	27
White perch	70	31	1	60	30

* Includes some fish taken offshore in the New England trawl fishery.

also would spawn in the interim, increasing the reproductive potential of the resource. Only scattered information is available on numbers of young taken by pound nets, haul seines, shrimp trawls, and other gears, and the tendency has been to minimize the effects of such predation. Recent observations on the composition of so-called trash fish catches in the Virginia pound-net fishery are impressive, however, and suggest that the problem merits further investigation. Five lifts of four pound nets in June and July 1958 took approximately 25,000 pounds of fish, of which about 55 per cent was sold to crabbers for bait. By weight, a little more than half this catch of scrap fish was menhaden and other non-food fishes, but there were considerable numbers of small butterfish, gray sea trout, spot, bluefish (*Pomatomus saltatrix*), and other potentially valuable food fishes (Table 3). The shrimp fisheries of the South Atlantic coast also take large numbers of small food fishes. The effects of these removals upon the fisheries of the Chesapeake and Middle Atlantic regions have never been investigated adequately (Atkinson *et al.* 1951)[3].

Most of the important species taken in Chesapeake Bay perform annual migrations, north in summer and south in winter. Older fish apparently do not enter the Bay in proportion to their true abundance, but instead continue their migrations farther north. Thus the Middle Atlantic fisheries might benefit at the expense of the Chesapeake and South Atlantic regions by stringent measures taken to increase escapement of small fish. Under the present system, whereby the States reserve the right to manag their own fisheries, it is not likely that souther fishermen would agree to restrict themselve for the benefit of someone else.

TABLE 2.—*Catch and value of certain food fishes e. ploited principally by pound net, haul seine, an otter trawl along the Atlantic coast of the Unite States in 1955*

Species and Gear		Weight in pounds	Value in dolla
Species	Scup	44,343,000	2,293,0(
	Alewife	47,155,000	551,0(
	Croaker	14,002,000	1,184,0(
	Flounders	62,847,000	8,015,0(
	Butterfish	7,959,000	680,0(
	Gray sea trout	9,287,000	804,0(
	Spot	8,126,000	715,0(
	Shad	8,599,000	1,422,0(
	Striped bass	4,937,000	1,112,0(
Gear	Pound net	104,901,000	3,570,0(
	Haul seine	30,919,000	2,511,0(
	Otter trawl	115,341,000[1]	13,369,0(

[1] Exclusive of New England trawl fishery.

POSSIBILITIES FOR MANAGEMENT

Under these circumstances it is difficult to s how these fisheries could be managed efficient by conventional methods, such as size limit catch quotas, mesh regulations, and the lik Virginia, for example, specifies minimum si limits for all important marine species, b these have no obvious biological basis and a not seriously enforced, for under present met ods of fishing few, if any, undersized fi would survive if released. Almost all the scr fish of species used as food listed in Table were below legal size, about two-thirds of a fish of these species caught in the period und investigation. All scrap butterfish and bluefi were below legal size limits of 7 and 8 inch respectively, and 97 per cent of all scrap wea fish were below the 9-inch legal limit for th species. From time to time it has been su gested that mesh size of pound nets shou

[3] ATKINSON, C. E., G. ROBERT LUNZ, J. L. McHUG E. W. ROELOFS AND RICHARD E. TILLER. 1951. T destruction of small fish by the shrimp trawlers Pamlico Sound, North Carolina. Appendix to minu of Chesapeake Bay Section, 20th Annual Meetir Atlantic States Marine Fisheries Commission, 36 p

e increased to allow these small fish to escape, ut the argument is always raised that this ould cause fish to gill, interfering with effi- ent net operation. Some years ago the Gen- al Assembly of Virginia instructed the Com- ission of Fisheries to investigate this prob- m, and records state that tests were conducted nd proved that small fish did gill in the nets Houston, 1929). No details of experimental

ABLE 3.—*Estimated numbers and actual weights of principal food fishes in five lifts of a series of four pound nets in the Virginia waters of Chesapeake Bay, June and July 1958*

Species	Food Fishes		Scrap	
	Estimated numbers	Total weight	Estimated numbers	Total weight
tterfish	9,250	1,850	28,360	2,852
oaker	6,342	4,502	0	0
y sea trout	7,500	2,500	5,927	1,041
ot	3,279	1,092	1,263	192
efish	0	0	1,100	210
nhaden	0	0	64,408	7,694
others	2,214	991	12,573	1,302
als	28,585	10,935	113,631	13,291

ocedures are available, and it is unlikely that ey were conducted according to established ientific methods. Here again the mixed catch uld work against effective utilization of a gulation based on mesh size, for an increase ficient to allow undersized butterfish to es- pe would release considerable numbers of nder-bodied species like weakfish or blue- h (Neville and Perlmutter, 1941). To com- cate matters further, the crab-pot fishery de- ds to a large extent on pound-net scrap for t, and demand for bait often exceeds the sent supply.

Catch quotas would be equally impractical impose upon gears that take several different cies in important quantities, for this might d to under- or over-exploitation of others. reover, the principal gears do not all operate the same season, hence complications would se from the necessity to prorate quotas ong gears.

The shrimp fisheries of the South Atlantic st present another complication. These fish- s are prosecuted for the express purpose of hing highly-desirable shrimp, worth far re per pound than any other species taken the trawls. The possibility of restricting mp fisheries to reduce rates of removal of valuable species seems remote indeed.

Salt water sport fishing is growing steadily in importance along the entire Atlantic coast. Sport catches of some species rival commercial catches in quantity. Catch restrictions would be extremely difficult to enforce, and probably would not be desirable even if feasible. The recently-formed Virginia Salt Water Sport Fishing Association is recommending voluntary limitation of sport catches, and this method has much to recommend it. There is good reason to believe that fishermen would derive more sport from their fishing if they were to release their catches. Tag returns have shown that croakers in Virginia do not move about much once they have become established in Chesapeake Bay and its tributaries in summer (Haven, *in press*). This has been confirmed in striking fashion by C. E. Richards, who has found a directly inverse relationship between catch per angler and numbers of anglers per boat. In other words the catch of croakers per boat in Virginia is the same, no matter how many lines are fished. Hence the most successful croaker fisherman will be the one who goes out alone. It follows that, by releasing his fish, an angler should receive proportionately more strikes.

MASS MANAGEMENT

Short of a drastic revision of fishing methods, to reduce or eliminate the random exploitation of fishery resources now characteristic of much of the Atlantic coast, it is difficult to visualize just how these fisheries can be managed for optimum yield by official regulation. One intriguing prospect is the thought that such fisheries might be subject to management *en masse*, rather than as a series of distinct species. This would be a much more sophisticated approach to the management of all fisheries, but at least two substantial advances in knowledge and attitudes will be necessary before this enlightened approach can be evaluated: deeper understanding of the interactions of species one with another and with the physical and chemical conditions of their environment, and greater appreciation of the economic, social, and political implications of an intelligent management program. This is particularly important in a region dissected into as many political subdivisions as the United States Atlantic coast, in which strong traditions of State and individual rights to the harvest of the sea are stoutly defended.

SOCIAL IMPLICATIONS

It is no accident that the various international fishery commissions have been the most successful organizations yet to tackle scientific fishery management. By their very nature these commissions have been protected from undue interference by local pressure groups. Fishery science is young, still feeling its way in unfamiliar directions. It requires freedom to exercise imagination in adapting old principles and formulating new. Perhaps the most telling criticism that can be levelled at fishery science today is that it stays too much in familiar and narrow pathways. When fishery legislation can be promoted or enacted without prior benefit of scientific knowledge and without provision to obtain it, fishery research and management go their separate directions and progress is slow at best. Unfortunately, most of our fishery research agencies face such difficulties still. The coordination of research and management, properly controlled by qualified and unbiased supervisory bodies, that gives international fishery commissions their strength, could be imitated with profit in all fishing areas.

The controversies that have raged between the States of Maryland and Virginia over the years with respect to mutual fishery problems require social and political as well as biological understanding for their solution. Recent deliberations of a commission appointed at the direction of the U. S. Supreme Court to find a solution to fishery problems in the Potomac River have brought forth a proposal that a body be appointed with full authority to conduct research and formulate management policies for the river. This proposal, which applies principally to the oyster resource, recommends leasing of barren public grounds, formerly productive but now ruined by overfishing, rather than a program of repletion by the two States. If adopted in full this may prove to be the most advanced step yet taken toward management of any Atlantic coastal fishery resource. Properly secured from interference, and staffed with competent people, such a body can hardly fail in its purpose, and can set a pattern for all Atlantic coast states to follow.

Lest the impression be left that scientists are infallible, and that all would be well if they were free to exercise control of research and management, a word must be said about scientific achievement. Marine research is one of the most fascinating, yet one of the most difficult fields of science. With few exceptions it ... sponsored by government or by the Unive... sities, pay scales are too low, and undue r... strictions are placed on thought and creati... effort. As a consequence far too few first-cla... students are attracted into the field, and pro... ress has suffered seriously in the past and w... continue to suffer for some time after the ... obstacles are removed. We as biologists a... doing marine science a disservice when we f... to drive these points home at every opportunit... and when we compromise our principles u... duly in the interest of expediency.

ECONOMIC IMPLICATIONS

The Atlantic coastal fisheries are still pu... sued in large part by small independent ope... tors who are limited by financial and oth... considerations to a single type of fishing ... tivity, or at best a few local fisheries. Becau... the average age of most important species ... low, especially in Chesapeake and South A... lantic waters, and a particular year class co... tributes significantly to the fisheries usua... for only one or two years, and because ... number of factors act to cause large variatio... in year-class strength or availability, the supp... of many species is notably erratic. This h... a double effect, to which all fisheries are su... ject to some degree, producing low incom... in times of scarcity and low prices in times ... plenty, and strong opinions on the part ... watermen as to the causes of their perso... economic difficulties.

Maintenance of a maximum sustained b... logical yield might be relatively simple if t... sole purpose of fishing were to obtain fo... Fluctuations in abundance of individual spec... would be relatively unimportant, for variatio... in total productivity probably are less viol... than variations in abundance of a single speci... Application of these principles is infinit... more complex in a prosperous country l... the United States, where profit is the sole m... tive of commercial fishermen. This complex... is implicit in the terminology of fishery scien... where *optimum* rather than *maximum* is p... ferred with reference to sustained yields.

Where profit is the primary motive, as ... always will be in an economy based on priv... enterprise, fishermen tend to exploit the m... desirable varieties, at the places and times ... which they can be caught and landed m... profitably. Fluctuations in the supply h... serious economic effects, especially upon ... small operator with limited resources, a...

hough profits may be large in good times, shermen suffer hardship when the supply is oor (McHugh and Bailey, 1957). In desperaon they are apt to seek drastic remedies that ore often than not may restrict fishing operaons unnecessarily, rather than recognize the eed to set aside funds earned in favorable easons to cover expenses of recovery from oor years. Furthermore, there is an ever-presnt tendency to confuse effects of economic nd social factors with those imposed by a anging biological supply, often leading to tter confusion in thought and action. Perhaps ne most efficient organization will be a large rporation which exploits a variety of marine sources over a wide area and is sufficiently exible to shift emphasis in response to changng abundance. Diversification would provide otection against poor seasons by spreading rofits derived from periods of abundance, and nnual earnings would be more uniform. There ould be fewer spectacular profits or losses an in the past, brand names would be possile and practical, and competitors who ignored could not maintain standards of quality and pply would be suppressed. Under this sysm, technological research provides the most mediate results, to improve catching, hanling, and processing methods, to improve and aintain quality standards, and to develop ore effective marketing procedures. Biological search also is necessary under this economic heme, for the resource must still be prcted against over-exploitation, but even when is successfully applied, scientific knowledge ill not eliminate effects of variations in abunnce of individual species, hence is unlikely impress the fisherman in a region where treme fluctuations occur. Perhaps most imrtant of all is the need for education, to arify the purposes of marine research, to spel confusion regarding relative importance biological, social, and economic effects, and emphasize the importance of long-term, as ll as short-term planning, with maximum eedom from transitory problems that cloud ain issues.

CONCLUSIONS

The conventional approach, by methods dened to foster management for optimum susned yield for each important species, holds le promise for most of the migratory food hes exploited in inshore waters of the Atlan coast. Several important species are caught significant quantities by each of the major gears, so that management for optimum yield of one species, even if desirable, would involve over- or under-exploitation of others. Each species is caught in important quantities by more than one gear, and these gears may operate at different times of year, and in totally different areas, so that catch and effort would be extremely difficult to control. For most species annual mortality rates, whether by death or emigration, are high, especially in southern waters, and growth rates probably are not sufficient to maintain maximum biomass beyond the first year of life, so that measures to increase average size or age at capture probably would decrease rather than increase catches. Management for optimum yield, even if it were desirable for a species as a whole, probably would favor northern states to the detriment of southerly fisheries, for older and larger fish of many migratory species, whose numbers would be increased by such measures, are not available in southern waters in proportion to their real abundance. Sport fisheries take large numbers of many major commercial species, and it would be almost impossible to apply management regulations to this fishery, and probably not at all desirable. A formidable obstacle also is lack of cooperation between Atlantic coast states in reaching a mutually satisfactory basis for management of joint resources.

Is there then any point in continuing present regulations, in contemplating new, or in continuing scientific research? The answer is definitely yes. We do not yet know enough to say what regulations are necessary, but we should guard against exploitation so heavy that reproduction will be affected, and research must still tell us how. For maximum results research should take less familiar pathways. Several lines of inquiry offer promise: (1) trawl surveys to measure changes in abundance of young, for prediction and for use in seeking causes of changes in abundance; (2) investigations of seasonal and annual changes in biomass of the entire resource, irrespective of species, partly to explore the possibility of management *en masse;* (3) attention to experimental management, a neglected method that might produce results that otherwise cannot be attained; (4) studies of inter-related organisms, such as bottom fauna and plankton, to detect at least the major features of the cycle of productivity in estuarine waters, and to assess effects of industrial and urban development upon important estuarine

spawning and nursery grounds; (5) research on biology and epidemiology of parasites and diseases; (6) investigations of metabolic rates and efficiency of food conversion at various ages and under various conditions; (7) studies of reactions of various species to external stimuli. These are only some of the promising fields to be explored.

In the meantime, while mandatory regulation is of doubtful value, from lack of biological knowledge and from complications inherent in fishing methods, some success might be achieved by voluntary modification of fishing operations, one form of experimental management. It is unlikely that we shall ever have sufficient information to give unequivocal answers to our fishery problems, but that should not prevent us from taking steps based upon intelligent application of facts now at our disposal. Success of this approach will depend upon aggressive educational programs, far more substantial than any now underway or heretofore attempted. In some respects a shift to this type of contact with the fishing industry would bring about more progress in the long run than further research activity at present levels of performance.

Along with biological and educational work should go more adequate investigations of economic, social, and political factors, potent influences in the interaction of fishery resources with their important predator, man. Methods by which we hope to manage these fisheries are based on the assumption that the primary purpose of fishing is to supply food, whereas profit is the sole motive of American commercial fishermen. Under such conditions fisheries can be prosecuted most efficiently under private, rather than public management, and this involves complex social adjustments. A fresh approach to our coastal fishery problems is sorely needed and will bring rich dividends.

LITERATURE CITED

HAVEN, DEXTER, S. 1958. Migrations of the croaker *Micropogon undulatus,* as indicated by tag returns. Copeia, *in press.*

HOUSTON, HARRY R. 1929. Biennial report of the Commission of Fisheries of Virginia for the 30th and 31st years, July 1, 1927, to June 30 1929. Richmond, pp. 1-23.

McHUGH, J. L. AND ROBERT S. BAILEY. 1957. History of Virginia's commercial fisheries. Va. Journal of Science, Vol. 8, No. 1, pp. 42-64.

NEVILLE, WILLIAM C. AND ALFRED PERLMUTTER 1941. A study of certain marine fishery problems of Suffolk County, Long Island, New York A survey conducted by the U. S. Department of the Interior, Bureau of Fisheries, in co-operation with the Board of Supervisors, Suffolk County New York: pp. 1-36.

TAYLOR, HARDEN F. 1951. Economics of the fisheries of North Carolina. *In* Survey of Marine Fisheries of North Carolina. Univ. of N. C. Press, Chapel Hill, xii + 555 pp.

YOUNGER, ROY R. AND JAMES A. ZAMOS. 1955. New Jersey's marine sport fishery. Misc. Rept. N. Fisheries Lab. No. 16, pp. 1-28.

Cricotopus bicinctus, a Midgefly Resistant to Electroplating Wastes

EUGENE W. SURBER

U. S. Department of the Interior, Bureau of Sport Fisheries and Wildlife
Branch of Federal Aid, Atlanta, Georgia

ABSTRACT

In polluted stretches of Michigan rivers, larvae of the midgefly, *Cricotopus bicinctus* (Meigen), were found to be particularly resistant to electroplating wastes containing hexavalent chromium, cyanides, and copper and to low oxygen levels. This insect survived in the Clinton River and matured in concentrations of chromium as great as 25 p.p.m., copper to 2.2 p.p.m and cyanides to 3.2 p.p.m. In waters receiving such plating wastes, the only other common bottom invertebrates were the annelids, *Limnodrilus* and *Tubifex,* and a midge tentatively identified as a species of *Pentapedilum.*

INTRODUCTION

Several times during the course of pollution surveys of warm-water streams in Michigan, a midgefly species was encountered which had outstanding resistance to chemical pollution, particularly electro-plating wastes containing hexavalent chromium, cyanides, and copper. It was identified from the larval stages as *Cricotopus bicinctus* (Meigen).

On May 12, 1957, the writer forwarded specimens of larvae, pupae, and adults collected October 4, 1955, from the Clinton River at Rochester, Michigan, to the U.S. National Museum for verification of the identification. On that date, this species was by far the predominant midge in the river. The material was collected during an emergence period. Dr. Paul H. Arnaud, Jr., Insect Identification and Parasite Introduction Section, U.S. National Museum, on June 10, 1957, confirmed the determination tentatively as follows: "I have compared the terminalia of some of the males which you have sent with published figures of the male terminalia of *Cricotopus bicinctus* (Meigen), and find that they closely agree. I would therefore agree with your tentative determination."

The full grown larva (Figure 1) is five millimeters in length, rather stout-bodied and dark green or bluegreen in color with a yellowish, short, and rounded head. The labial plate, which has thirteen teeth, is unusually prominent and projects from the head as illustrated in Figure 1 E. This midge is believed to feed in polluted waters on resistant bluegreen or other algae growing on the surfaces of stones. Unlike *Tendipes decorus, T. riparius,* and other midges with red larvae which store oxygen in hemoglobin (Lindeman, 1941), *Cricotopus bicinctus* apparently does not have the ability to survive periods of zero oxygen which occur in some streams only at night.

This paper describes quantitative distribution of *Cricotopus bicinctus* in the presence of electroplating wastes in the Clinton River and gives other examples illustrating the resistance of this midge to pollutional conditions. Data from the Clinton River was originally presented in a report of the Michigan Water Resources Commission entitled "Results of a Biological Study of the Clinton River in the Vicinity of Pontiac, Rochester and Utica, Michigan, October 4, 1955." At that time the writer was Aquatic Biologist with the Commission. Other data are from staff reports of the Commission.

CLINTON RIVER INVESTIGATION

A survey of the Clinton River on June 14, 15 and July 6, 1955, followed a rather un-

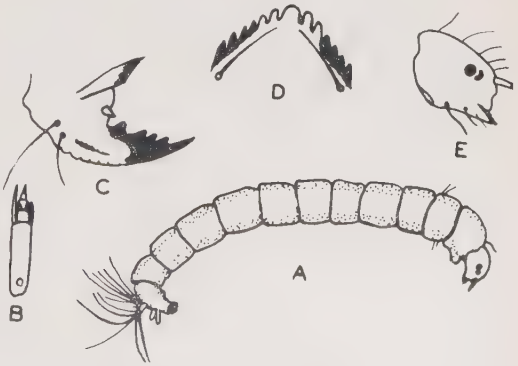

FIGURE 1.—Sketch of larva of the midgfly *Cricotopus bicinctus* (Meigen) showing details of head, and mouth parts of a Clinton River, Michigan, specimen. (A—larva; B—antenna; C—mandible; D—labium; and E—head).

usual series of pollutional events which twice led to the suspension of the use of the Clinton River as a source of water supply by the City of Utica because of excessive concentrations of hexavalent chromium. Figure 2 shows the approximate locations of the chemical and biological sampling points used during the survey.

The principal source of chemical pollution was at Pontiac where the sewers of the city receive wastes from several electro-plating industries. These wastes together with the city's sewage pass through municipal treatment facilities where secondary treatment by activated sludge and trickling filters is provided prior to discharge to Clinton River. The treatment was incapable of coping with the electro-plating wastes, especially during periods when concentrated plating solutions were disposed of in batches to the city sewers.

Nature and Extent of Pollution

The first record of excessive concentrations of chromium in the Clinton River was on July 9, 1955 when hexavalent chromium reached 70 parts per million *below* the Pontiac Sewage Treatment Plant.. But before this, on June 14 and 15, a Staff report of the Water Resources Commission had shown that small quantities of dangerous plating wastes wer entering the river *above* the Pontiac Sewag Treatment Plant and that conditions were criti cal for aquatic life in the river. On these days in the 22 mile stretch between Pontiac an Utica, concentrations of cyanides in the rive ranged from 0.00 to 0.69 p.p.m.; hexavalen chromium from 0.00 to 0.29 p.p.m. and coppe from 0.00 to 2.2 p.p.m. (Table 1). It i evident that in addition to plating waste entering the river above the treatment plan such wastes were also being discharged throug it; for filter plant effluents on June 14 and 1 showed maxima of 23.3 p.p.m. cyanide, 14. p.p.m. hexavalent chromium and 14.0 p.p.n copper. In the activated sludge plant effluen 13.0 p.p.m. cyanide were found.

The data for dissolved oxygen at M-5 below the Pontiac Sewage Treatment Plant ar at Rochester (Rochester Road) showed low dissolved oxygen on July 6, than during th earlier survey of June 14 and 15. On th date, the dissolved oxygen content of th river water was only 2.8 p.p.m. at Rocheste This alone is a critical level for such botto animals as caddisfly larvae and mayfly nymph as well as fish and other aquatic organisms.

A Michigan Department of Health Repo summarizing the results of analyses for hex

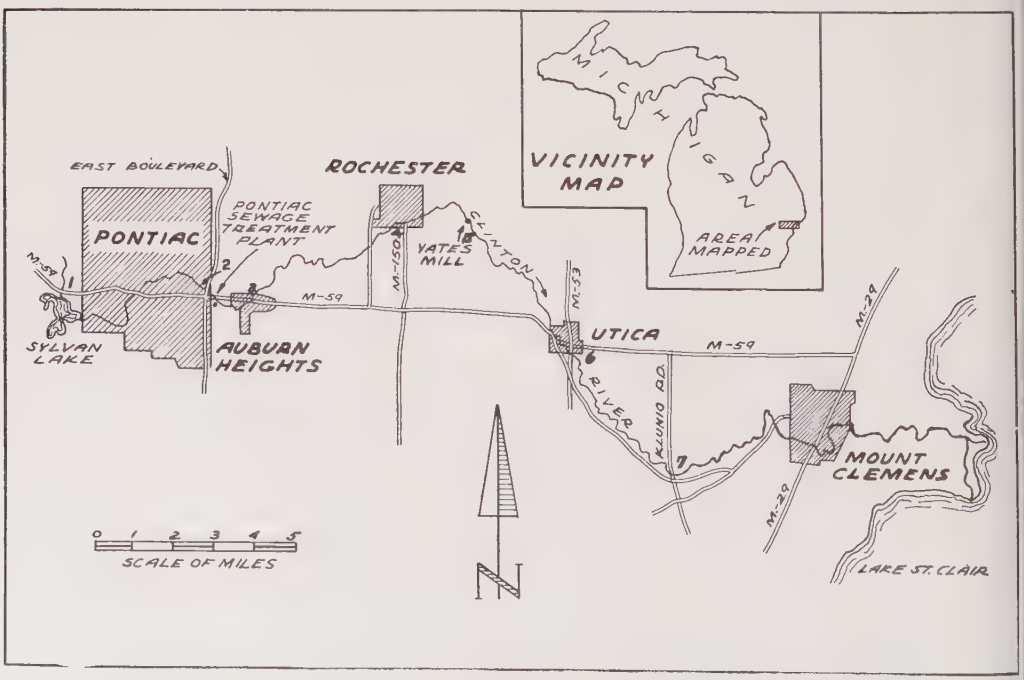

FIGURE 2.—The Clinton River in the vicinity of Pontiac, Michigan showing general location of chemical and biological sampling points.

TABLE 1.—*Concentrations of chemicals at various locations in the Clinton River on June 14, 15 and on July 6, 1955*

Sampling location	Date 1955	Concentrations in river water parts per million D.O.	CN	Cr^6	Cu
ast Boulevard.....	June 14	8.8	0.22	0.02	0.00
	June 15	7.8	0.18	0.00	0.16
	July 6	9.8	0.27	0.11—	0.00
-59 below Pontiac	June 14	4.8	3.20	0.00	2.20
	June 15	4.8	0.41	0.29	0.32
	July 6	3.0	0.16	0.08	0.14
ochester ochester Road)...	June 14	6.8	0.02	0.00	trace
	June 15	8.6	0.69	0.04	0.50
	July 6	2.8	0.02	0.00	0.00
ates Mill Railroad idge.....	June 14	8.4	0.00	0.00	0.00
	June 15	8.4	0.47	0.00	0.40
	July 6	6.8	0.00	0.00	0.00
-59 at Utica	June 14	7.6	0.00	0.00	0.00
	June 15	7.4	0.69	0.00	0.50
	July 6	7.0	0.00	0.00	0.00

alent chromium in 486 samples from various linton River Sampling Stations during the eriod from June 18 to July 8, 1955, showed he following frequencies of concentrations of exavalent chromium:

0 -0.1 p.p.m.	276 samples
0.1-0.2 p.p.m.	72 samples
0.2-0.3 p.p.m.	77 samples
0.3-0.4 p.p.m.	6 samples
0.4-0.5 p.p.m.	12 samples
0.5-1.0 p.p.m.	25 samples
1.0-2.0 p.p.m.	15 samples
2.0-3.0 p.p.m.	3 samples
	486 samples

During the period July 12 through 18, 164 ditional water samples were taken and these owed the following ranges in hexavalent romium concentrations:

0.0-0.1 p.p.m.	94 samples
0.1-0.2 p.p.m.	11 samples
0.2-0.3 p.p.m.	26 samples
0.3-0.4 p.p.m.	23 samples
0.4-0.5 p.p.m.	10 samples
	164 samples

A second period of concentrated discharge chromium began entering the Clinton River from the Pontiac Sewage Treatment Plant during the afternoon of September 14, 1955. At Auburn Heights, sampling showed 10 p.p.m. hexavalent chromium at 6:45 p.m., 25 p.p.m. at 9:20 p.m., 20 p.p.m. at 11:00 p.m., 20 p.p.m. at 3:45 a.m. on September 15 and 16, after which the quantities diminished until at 11:30 p.m. only 0.02 p.p.m. of chromium was present in the river water at Auburn Heights. This batch of chromium did not reach its maximum at Rochester until about 3:55 p.m. September 15, when 20 p.p.m. was recorded. The duration of high concentrations at this point was about four hours. The peak of chromium concentration apparently reached Yates Mill (about 15 miles downstream) about 6:10 p.m., September 15, when 6.0 p.p.m. was recorded. At Utica, the chromium began arriving about 9:30 a.m. September 16, when 3.5 p.p.m. were recorded. The peak concentration here was about 5.0 p.p.m. recorded between 11:45 a.m. and 2:15 p.m. when amounts began to diminish.

The above data are believed sufficient to show that the Clinton River in 1955 received considerable pollution from dangerous plating wastes. The river also received the effluents from sewage treatment plants at Rochester and Utica, neither of which had been found to contain electro-plating wastes. The plant at Pontiac was rendered largely ineffective during this period by overloads of electro-plating wastes.

Biological Effects of Pollution

The biological survey of October 4, 1955, was made 18-20 days after the passage of the last high chromium concentration. Two square-foot bottom samples, were collected with a stream bottom sampler at the sampling stations shown in Figure 2 and described in Table 2.

The results of the bottom sampling are given in Table 3, which shows the number of bottom animals of various kinds per square foot, and the distribution of *Cricotopus bicinctus*.

Bottom animals were classified as clean-water, facultative (able to live under moderately polluted as well as clean-water conditions) and pollution-tolerant. The classification symbols used are C, F, and P, respectively, to describe pollutional status.

Clean-water conditions in the riffle areas of streams are indicated by the presence of a variety of species usually including species of snails, mayflies, caddisfly larvae, beetle larvae, and midgefly larvae.

A large variety of animals occurred at Station 1 above Sylvan Lake which is above all sources of pollution. Net-spinning caddisfly larvae (mostly species of *Cheumatopsyche*), fingernail clams, and snails were very abundant. The number of species of all animals was 19+ in one sample and 24+ in a second. Several species of midgeflies were present, but the occurance of 48 *Cricotopus bicinctus* per square foot in one sample and nine in another was of particular interest because this species not only survived the chemical pollution farther downstream, but seemed to thrive on it.

In the two samples taken at this Control Station, 72.1 percent of all animals present were clean-water animals. This may be compared with 0.4 percent for clean-water animals at the East Boulevard Station immediately above the sewage treatment plant where nearly all species of bottom animals were eliminated or could not live, apparently because of electroplating wastes. The only species which occurred commonly at East Boulevard was the midgefl *Cricotopus bicinctus,* originally considered h the writer to be a facultative species becau it is apparently unable to survive very lo oxygen conditions. Downstream about a mi at Auburn Heights, probably because of e posure to critically low oxygen condition these midge larvae were virtually absent. Tl only other bottom organism found here w *Limnodrilus.*

Above the sewage treatment plant at R chester, about 12 miles below Pontiac, on five and three species, respectively, occurr in the two samples taken there. The midge species *Cricotopus bicinctus* occurred in lar numbers (300 in one sample, 259 in a second along with *Limnodrilus, Tubifex, Procladi* and *Pentapedilum* (?).

At the time of the collection of the sampl and in all samples containing large numbe of larvae of *Cricotopus bicinctus,* there we many pupae and some adults of the speci In one sample at Rochester, of a total of 2 specimens of the species, 174 were larvae a 85 were pupae. At Utica, one sample contain 266 larvae and 92 pupae. The presence both full grown larvae and pupae indica that these organisms had survived the criti concentrations of toxic chemicals to whi they had been exposed over an unknown h extended period.

Below the dam at Yates Cider Mill, t number of species increased to an average eight per square foot, but the lack of caddis larvae, mayfly nymphs, parnid beetle larv snails and clams of any kind indicate t damaging effects of the toxic chemicals. Tu ficids were more abundant here than upstrea particularly along the Cider Mill side of t river (the left side of the river) where a to of 285 tubificids per square foot were collect in one sample. Midgefly larvae of *Cricotop bicinctus* were as abundant at Yates Mill at Rochester. A medium-sized red midge la with 14 black labial teeth of quite unifo size, lacking gills on the 10th and 11th s ment (identified tentatively as belonging the Genus *Pentapedilum*), occurred in c siderable numbers at Yates Mill and even m abundantly at the Rochester station. Fish larvae of *Chauliodes* that were taken h probably been washed downstream from trout stream entering above the mill dam.

At Utica, 22 miles downstream from Por ac, there were few animals of any kind exc *Cricotopus bicinctus* larvae. These occurred

TABLE 2.—*Location and description of biological sampling stations on the Clinton River.*

Station No.	Location	Approximate miles above or below Pontiac Sewage Treatment Plant	Description
1	M-59 above Sylvan Lake	6.75 (above)	Unpolluted clear water
2	East Boulevard above S.T.P.	0.20 (above)	Rubble, coarse gravel. Contains plating wastes originating in Pontiac Creek
3	Auburn Heights	4.50	Coarse gravel, rubble. Unusual growth of algae (*Stigioclonium*) on stones which were black on their undersides.
4	Rochester at Rochester Road	11.70	Stones not black on undersides. Coarse gravel, rubble
5	Below Mill Dam at Yates Cider Mill	14.90	Stones covered with true mosses or algae forming long strands several feet in length. Foaming below Mill Dam due to detergents in the river water. Coarse gravel, rubble
6	Below M-59 at edge of City of Utica	21.70	Small gravel sampled
7	Klunio Road	29.20	Small gravel samples. A, in gravel covered with algae, B in midstream in gravel recently shifted.

even larger number than at the two upstream stations.

Larvae of the midgefly, *Cricotopus bicinctus,* thrived in the Clinton River between Rochester and Utica, and above the Pontiac sewage treatment plant, in spite of the presence of electro-plating wastes. The chemical pollution was evidently too severe to be survived by the normally hardy tubificids which would thrive in this section of river under ordinary conditions.

Occurrence of Cricotopus bicinctus in Other Polluted Waters

Additional evidence of tolerance of *Cricotopus bicinctus* to pollution by electro-plating wastes is shown by information gathered in February 1955 from the South Branch of the Raisin River (flow about 20 c.f.s.) near Adrian, Michigan. Here wastes from two industries engaged in electroplating had nearly destroyed bottom animals in a naturally rich stream. Above the entrance of the wastes, the composition of which is shown in Table 4,

TABLE 3.—*Kinds and numbers of bottom animals per square foot from sampling stations in the Clinton river near Pontiac, Michigan, October 4, 1955*

Kinds of animals	Pollutional Status	Average number of animals per square foot Station number and location						
		1 M-59 above Sylvan Lake	2 E. Blvd. above S.T.P.	3 Auburn Heights	4 Rochester Main St.	5 Yates Mill	6 M-59 at Utica	7 Klunio Rd. below Utica
Nematoda:	F	4	1	—	—	—	—	—
Dugesia	C	9	—	—	—	—	—	—
Limnodrilus	P	3	3	10	32	129	2	694
Tubifex	P	—	1	—	1	30	—	350
Amnicola	C	87	—	—	—	—	—	—
Sphaerium	P	15	—	—	—	—	—	—
Pisidium	P	109	—	—	—	—	—	—
Campeloma	F	2	—	—	—	—	—	—
Ferrissia	F	2	—	—	—	—	—	—
Helisoma	C	1	—	—	—	—	—	—
Hyalella azteca	C	3	—	—	—	—	—	—
Asellus	P	1	—	—	—	—	—	—
Cambarus propinguus sanborni	C	1	—	—	—	—	—	—
Pseudocleon nymphs	C	14	—	—	—	—	—	—
Stenonema nymphs	C	2	—	—	—	—	—	—
Enallagma nymphs	C	1	—	—	—	1	—	—
Psephenus larvae	C	13	—	—	—	—	—	—
Helichus larvae	C	1	—	—	—	—	—	—
Simpsonia larvae	C	1	—	—	—	—	1	—
Stenelmis larvae	C	36	1	—	—	—	—	—
Parnid beetles	C	2	—	—	—	—	—	—
Chauliodes larvae	C	—	—	—	—	2	—	—
Corydalus cornutus larvae	C	—	—	—	—	2	—	—
Helicopsyche boreais larvae	C	58	—	—	—	—	—	—
Hydropsychidae, lmostly, *Cheumatopsyche* larvae	C	218	—	—	—	—	—	—
Neureclipsis crepuscularis larvae	C	1	—	—	—	—	—	—
Cricotopus bicinctus larvae and pupae	F	29	121	1	280	285	459	132
Microtendipes pedellus larvae	C	6	—	—	—	—	—	—
Procladius sp. larvae	P	—	—	—	—	2	—	—
Calopsectra exiguus larvae	F	10	—	—	—	—	—	—
Pentapedilum sp. ? larvae	P	—	—	—	64	28	3	—
Pentaneura flavifrons larvae	C	1	—	—	—	1	5	—
Polypedilum convictum larvae	F	1	—	—	—	—	—	15
Simulium larvae	F	2	—	—	—	—	—	—
Unknown Dipterous larvae	F	(?) —	—	—	—	1	2	—
Chrysops larvae	F	—	—	—	—	—	1	—
Total number of animals (average)		623	126	11	378	479	472	1191
Number of species (average)		22	4	2	4	8	6	4
Percent clean water (C)		72.1	0.4	0.0	0.0	1.0	1.0	0.0
Percent facultative (F)		7.5	96.8	9.0	74.0	59.5	97.7	12.3
Percent pollution-tolerant (P)		20.3	2.7	90.9	25.9	39.3	1.0	87.6

TABLE 4.—*Concentrations of chemicals in industrial effluents and South Branch of the Raisin River waters near Adrian, Michigan*

Sampling location	Date and time of collection		Concentration (p.p.m.)			
			Cyanides	Chromium	Copper	Zinc
Industrial effluent A	Feb. 8	9:15 a.m.	7.50	4.70	8.0	4.0
	Feb. 8	1:15 p.m.	7.00	2.40	6.6	0.0
	Feb. 9	8:40 a.m.	12.50	0.00	8.0	8.0
Industrial effluent B	Feb. 9	2:45 p.m.	11.00	2.80	5.7	0.0
	Feb. 9	2:55 p.m.	0.03	0.09	trace	0.0
Raisin River wastes						
M-34 Highway (control)	Feb. 9	8:30 a.m.	0.00	0.00	0.00	0.00
College Avenue—Adrian	Feb. 9	9:00 a.m.	0.55	0.01	0.30	0.00
Island Park—Adrian	Feb. 9	9:25 a.m.	0.24	0.01	0.15	0.00

Cricotopus bicinctus was abundant (395 per square foot) on February 9, 1955. Other bottom invertebrates such as larvae of *Hydropsyche, Cheumatopsyche* and simulids also occurred.

Below this control sampling station and after the entrance of the wastes, the river water had concentrations of pollutants shown in Table 4: Cyanides to 0.24 p.p.m., chromium to 0.01 p.p.m. and copper to 0.3 p.p.m. About 500 feet below the entrance of wastes *Cricotopus bicinctus* still occurred, but in reduced numbers: 15 and 21 per square foot in individual samples. A mile below the entrance of the wastes no *Cricotopus* were found but two miles below, this species constituted 38 percent of the bottom animals found and was exceeded in abundance only by *Limnodrilus*.

Earlier, in August, 1953, the Raisin River had received such a heavy batch of plating wastes that the water supply at Blissfield, 30 river miles below Adrian had become yellow with hexavalent chromium.

At Plymouth, Michigan in May 1954, *Cricotopus bicinctus* survived in numbers up to 30 per square foot in the Rouge River where they were exposed to at least 0.5 to 0.7 p.p.m. cyanides.

The species is hardy under ordinary pollution conditions involving domestic and industrial wastes aside from plating industries, as was demonstrated in the Kalamazoo River during October 19 and 20, 1953. Through the City of Battle Creek, the major bottom animals were eliminated. The number of species was reduced from 11 to 7. Clean-water animals decreased from 87.5 to 16.4 percent of the total number. Yet *Cricotopus bicinctus* survived under conditions of low oxygen which eliminated caddisfly larvae belonging to the Hydropsychidae, which were abundant above the city.

ACKNOWLEDGEMENTS

The writer is grateful to Mr. Milton P. Adams, Executive Secretary of the Michigan Water Resources Commission for permission to publish this article, to Mr. Loring F. Oeming, Chief Engineer of the Commission Staff for reviewing it, and to Dr. Paul A. Arnaud, Jr., U. S. National Museum, for verifying the identification of the midgefly specimens sent to the Museum.

Unless otherwise noted, chemical analyses were made by Russell Kreuger, Chemist of the Commission Staff.

LITERATURE CITED

LINDEMAN, RAYMOND L. 1941. Seasonal food dynamics in a senescent lake. American Midland Naturalist, Vol. 26, No. 3, pp. 636-673.

Test of 34 Therapeutic Agents for Control of Kidney Disease in Trout

KEN WOLF AND C. E. DUNBAR
U. S. Fish and Wildlife Service, Eastern Fish Disease Laboratory, Leetown[1], West Virginia

ABSTRACT

Sixteen strains of fish kidney disease bacterium were tested *in vitro* to determine their reaction to 34 therapeutic agents. On the basis of the results obtained ten of the drugs were employed in experimental therapy of kidney disease in eastern brook trout (*Salvelinus fontinalis*). Erythromycin at the rate of 100 milligrams per kilogram of fish per day (4.5 grams per 100 pounds of fish) for 21 days gave the best results. Other drugs gave only temporary benefit if any.

INTRODUCTION

Kidney disease has attained recognition during the past five years as an increasingly important source of mortality in salmonid fishes. It has been found in wild populations of trout and salmon, and it occurs fairly commonly in cold-water hatcheries where it infects the principal salmonids which are artificially propagated. Kidney disease is typically a chronic bacteremia and usually causes high mortality of infected fish. It is caused by an organism which Ordal and Earp (1956) consider to be a *Corynebacterium*. It is not known whether the apparent increase of kidney disease in recent years is due to spread of the infection or increased awareness and ability of many people to identify the disease, or to both.

In earlier research on the treatment of kidney disease the most promising results were obtained with sulfonamides. Rucker *et al.* (1951) employed sulfadiazine for treatment of kidney disease in blueback salmon (*Oncorhynchus nerka*) and found some suppression. They stated that some cures may have been effected, but the bacterium persisted in a small number of fish. Earp *et al.* (1953) found that sulfadiazine temporarily controlled the disease in blueback salmon, but that mortality recurred after treatment had been stopped. Snieszko and Griffin (1955) treated kidney disease in eastern brook trout (*Salvelinus fontinalis*) with several antimicrobials. They found that some sulfonamides were more effective than antibiotics, but that these sulfonamides only arrested the disease temporarily. In the most recent account of kidney disease therapy (Allison, 1958), the temporary effect of sulfonamide therapy was again observed. The objective of the present research, therefore, was to find a more effective and lasting treatment for fish kidney disease.

Thousands of antimicrobial drugs have been found, but relatively few have been accepted in general medical practice and fewer still tried on kidney disease of fishes. In medicine, the development of effective antimicrobial therapy usually follows the following pattern. Drugs are selected for *in vitro* screening according to the routes by which they must be administered, their spectra of effectiveness on other similar microorganisms, their toxicity to the patient, their side reactions, and the like. The disease organism is then propagated *in vitro* in the presence of the individual drugs. If a drug has little or no effect on the organism in the test tube, there is little liklihood that it will be effective in treatment. If, however, a drug is effective in inhibiting growth of the disease organism *in vitro*, there is a possibility that it will be effective *in vivo*. It is used then in experimental treatment of the infection. This method was employed in the present research.

In vitro SCREENING METHOD

The disk method of drug-sensitivity testing was used to determine the effect of 34 therapeutic agents upon 16 strains of the kidney disease bacterium that had been isolated during outbreaks of the disease among Pacific salmon in Oregon and Washington and among propagated trouts in western, central, northeastern and southeastern United States. Small filter paper disks which contain known concentrations of soluble drugs were placed on freshly inoculated surfaces of slants of a suitable agar

[1]P. O. Kearneysville, West Virginia.

medium. After adequate incubation the culture vessels were examined. Absence of bactrial growth around a disk indicated a killing or growth-suppressing effect by a drug (Figure 1).

Commercially prepared disks of high concentration were used to test 24 of the drugs. One drug, phenoxyethanol, is a liquid; candicidin is not sufficiently soluble in any of the common laboratory solvents, and these were tested by placing small amounts directly on the culture medium. The remaining eight drugs were tested with disks of our own preparation. Except for fungichromin which was used at 40 micrograms per disk, solutions of the other antimicrobials were prepared to contain 5 milligrams of drug per milliliter, and 0.02 milliliter (100 micrograms) was applied to dry, sterile, 6-millimeter filter paper disks. Disks were air dried at 37°C.

Mueller Hinton medium (Difco), supplemented with 0.1 percent l-cysteine hydrochloride and serilized at 10 pounds for 13 minutes, was used in 20 x 150 millimeter screw-cap test tubes. Freshly slanted surfaces were swabbed with a heavy suspension of a culture of the bacterium to be tested, and a single drug-impregnated disk was applied to the center. Each drug was tested in duplicate tubes. The temperature of incubation was 19°C., and th slants were incubated in the vertical positio At an average of 14 days after inoculatio (9 to 19 days) bacterial growth was sufficie to allow accurate determinations of effect Three additional determinations were made weekly intervals. Only the bottom half of th surface of a slant was considered in measurin the relative effectiveness of a drug.

In vitro SCREENING RESULTS

All strains of the kidney disease bacteriu were strongly sensitive to most of the ant biotics (Table 1). All strains were sensitiv in varying degrees to penicillin G, a phenom non noted by Earp *et al.* (1953), in the cultivation of the organism on embryonic ti sues. In contrast, cycloserine, eulicin, pol myxin B, viomycin, and neomycin produce little or no effect on the organism.

Although the amount of growth was great reduced, some growth usually occurred ne to the sulfonamide disks. The one exceptio was the Pisgah Forest, N. C., strain whic proved unusually sensitive to sulfonamide The nitrofurans produced a striking effect an virtually prevented growth in all the tub in which they were tested. Of the other thera peutic agents, phenoxyethanol strongly su

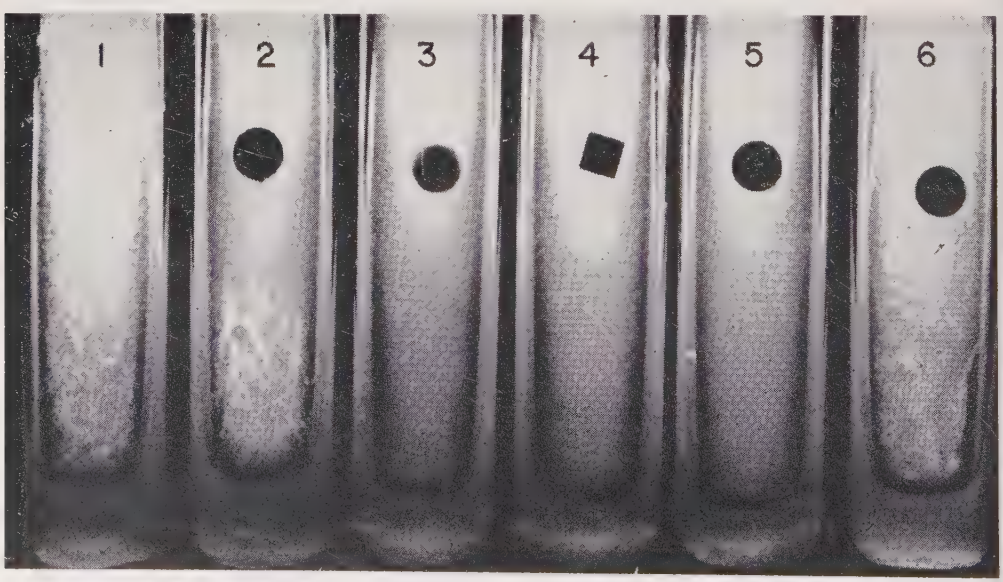

FIGURE 1.—Representative results obtained from *in vitro* drug sensitivity testing of the kidney disea bacterium: (1) surface of control tube is covered uniformly with bacterial growth; (2) growth of bacteri is prevented in a small but distinct zone around the penicillin-containing disk; (3) chlortetracycline (calc um) prevents growth throughout the tube; (4) sulfamerazine greatly inhibits the bacterium, but som growth is evident even close to the disk; (5) oxytetracycline prevents growth throughout the tube; and (6 viomycin is without effect on the bacterium.

TABLE 1.—*Results of using the disk method of sensitivity testing for 34 therapeutic agents on 16 strains of the kidney disease organism*

THERAPEUTIC AGENTS TESTED			LOCATIONS FROM WHICH CULTURES WERE ISOLATED															
Chemical Name	Trade Name or Synonym	Concentration Drug per disk	Berlin, N. H.	Bowman's Bay, Wash.	Butte Falls, Ore.	Chatachoochee For., Ga.	Cortland, N. Y.	Crawford, Nebr.	Issaquah, Wash.	Klickitat, Wash.	Leetown, W. Va.	Nooksack, Wash.	Oakridge, Ore.	Pisgah Forest, N. C.	Saratoga, Wyo.	Spring Creek, Wash.	Walhalla, S. C.	Winthrop, Wash.
Sulfonamides																		
sulfadiazine		300 micrograms	*	*	*	*	*	*	+	*	*	*	*	***	*	*	***	*
sulfamerazine		300 micrograms	*	*	*	*	*	*	*	*	*	*	*	***	*	*	***	*
sulfamethlthiadiazole	Thiosulfil[R]	300 micrograms	*	*	*	*	*	*	*	*	*	*	*	***	*	*	*	*
sulfadimetine	Elkosin[R]	300 micrograms	*	*	*	*	*	*	+	*	*	*	*	***	*	*	*	*
sulfathiazole		300 micrograms	*	*	*	*	*	*	*	*	*	*	*	***	*	*	*	*
sulfisoxazole	Gantrisin[R]	300 micrograms	*	*	*	*	*	*	+	*	*	***	*	*	*	*	*	*
triple sulfa		300 micrograms	*	*	*	*	*	*	*	*	*	*	*	***	*	*	*	*
Nitrofurans																		
nitrofurantoin	Furadantin[R]	300 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
nitrofurazone	Furacin[R]	300 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Other Agents																		
2-acetylamino-5-nitrothiazole	MK-51	100 micrograms	*	*	*	*	***	***	*	***	*	*	*	***	*	*	*	*
isonicotinoyl hydrazide	I N H	35 micrograms	*	†	†	†	#	†	†	*	*	*	*	*	†	*	*	*
para-aminosalicylic acid	P A S	100 micrograms		†	†	†	†	†	†	*	*	*	*	*	†	*	*	*
2-phenoxyethanol		0.02 milliliter	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***

TABLE 1.—Cont'd.—*Wolf and Dunbar.*

THERAPEUTIC AGENTS TESTED			LOCATIONS FROM WHICH CULTURES WERE ISOLATED															
Chemical Name	Trade Name or Synonym	Concentration Drug per disk	Berlin, N. H.	Bowman's Bay, Wash.	Butte Falls, Ore.	Chatachoochee For., Ga.	Cortland, N. Y.	Crawford, Nebr.	Issaquah, Wash.	Klickitat, Wash.	Leetown, W. Va.	Nooksack, Wash.	Oakridge, Ore.	Fisgah Forest, N. C.	Saratoga, Wyo.	Spring Creek, Wash.	Walhalla, S. C.	Winthrop, Wash.
Antibiotics																		
bacitracin		20 units	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
candicidin	AG-16	granule	***	***	***	*	***	***	***	***	***	***	***	***	***	***	***	#
carbomycin	Magnamycin[R]	15 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
chloramphenicol	Chloromycetin[R]	30 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
chlortetracycline	Aureomycin[R]	30 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
chlortetracycline, calcium		100 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
cycloserine	MK-65	100 micrograms	†	†	†	†	†	†	†	*	†	*	†	†	†	†	†	†
dihydrostreptomycin		100 micrograms	***	*	†	*	***	***	*	*	*	*	*	†	†	*	*	*
erythromycin	Ilotycin[R]	15 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
eulicin		100 micrograms	†	†	†	†	*	†	†	*	*	*	*	*	†	*	*	*
filipin		100 micrograms	†	†	†	†	†	†	†	*	†	*	*	*	†	*	†	†
fungichromin		40 micrograms	*	*	†	*	***	*	*	*	*	*	*	***	*	*	***	*
neomycin		30 micrograms	*	*	†	†	†	†	†	*	*	†	†	*	*	*	†	†
novobiocin		15 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
oxytetracycline	Terramycin[R]	30 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
penicillin		10 units	*	*	***	*	*	*	*	*	***	*	***	*	*	*	***	*
polymyxin B	Aerosporin[R]	30 micrograms	†	†	†	†	†	†	*	*	†	†	†	†	†	†	†	†
streptomycin		100 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
tetracycline	Achromycin[R]	30 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
thiocymetin		100 micrograms	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
viomycin		100 micrograms	†	†	†	*	†	*	†	*	†	*	†	*	†	†	*	†

† Organism resistant to the agent.
* Organism slightly sensitive to the agent.
*** Organism highly sensitive to the agent.
# Data not obtained.

pressed growth, and surfaces were devoid of growth in every case. I N H and PAS, two drugs used in therapy of human tuberculosis, were almost without effect.

EXPERIMENTAL THERAPY

Not all of the therapeutic agents which showed promise *in vitro* were used in the therapy trials. Several of the drugs can be administered only by injection; others are applied topically and are therefore not suited for experimental feeding. Some of the drugs had previously been employed in experimental therapy of kidney disease, and their therapeutic effects were known. Thiocymetin and candicidin, both of which strongly affected the kidney disease bacterium *in vitro,* were discontinued by their manufacturers before being marketed.

Facilities did not permit simultaneous comparison of all drugs selected for therapy, therefore, two trials were conducted.

First trial

Methods. For the first trial, Bellefonte, Pa., strain of eastern brook trout of uniform size (14.3 grams average) were distributed in small aliquots among identical troughs for a total of 100 fish per trough. They were infected with kidney disease by intraperitoneal injection of 0.2 milliliter of a newly isolated bacterium in a suspension, the turbidity of which was equal to McFarland Standard No. 2 to No. 3. Uninoculated and inoculated - but - not - treated fish were also kept for comparison.

Progress of the disease was observed in a small lot of fish kept for that purpose. Eleven days after inoculation, the kidney disease bacterium was identified in the kidneys of most of the fish killed for examination, and administration of the drugs was started. Two troughs of fish were used for each of the seven drugs tested (Table 2).

Drugs were thoroughly mixed with the fish's food, Cortland No. 6 diet, (Tunison *et al.,* 1952). The fish were fed twice a day at the rate recommended by Deuel *et al.* (1952) for eastern brook trout at 12.5 C. temperature. Fish were weighed at 10 and 11-day intervals, and the ration and drug adjusted accordingly. Sulfisoxazole, a sulfonamide recommended by Snieszko and Griffin (1954) was fed at the recommended dosage to serve as a basis for comparison of the relative effectiveness of the other drugs. All drugs were fed for 21 days,

TABLE 2.—*Mortality of eastern brook trout in the first trial of drugs used for a 21-day period of experimental therapy of kidney disease*

Drug	Daily dosage per kilogram of fish	Percentage mortality 33 days after treatment stopped
Carbomycin	40 milligrams	75.5
Erythromycin, crystalline base	40 milligrams	64.0
Furazolidone	100 milligrams	78.5
Nitrofurazone	100 milligrams	85.5
Novobiocin	40 milligrams	72.5
Sulfisoxazole	200 milligrams	1.5
Tetracycline	40 milligrams	72.0
None (uninoculated Controls)		0.0
None (inoculated Controls)		72.5

and the fish were observed for an additional 33 days. During therapy and for a week after, all dead fish were examined in order to determine the cause of death. For the remaining 28 days of observation only one dead fish per trough per day was examined.

Twenty-four days after termination of therapy, those fish which had been on sulfisoxazole were pooled, then equally divided among four troughs. Two troughs received an additional 12-day course of sulfisoxazole, but the remaining two troughs were not treated. All were observed for 78 days after treatment.

Results. Of the seven drugs tested none was found that had a better therapeutic effect than sulfloxazole (Table 2). There was good agreement in results among replicates, and as far as could be determined, there were no complicating infections. Like the other drugs used in this trial, nitrofurazone was highly effective *in vitro,* but fish treated with this drug suffered a greater mortality than those which received no treatment. Frequently they showed aversion to food which contained the drug, and after several feedings some of them lost motor stability and swam on their sides.

Except for the uninoculated controls and those fish which were given sulfisoxazole, mortality occurred in all lots from the time treatment stopped until the termination of observation (33 days). Fish which had been treated with sulfisoxazole began to die soon after redistribution. Most of the early mortality occurred among those which did not receive the second treatment. At 78 days, however, 70

percent of the twice-treated and 76 percent of the single-treated fish were dead.

SECOND TRIAL

Methods. Bellefonte, Pa., strain brook trout were also used for the second trial, but their average weight was then 33.4 grams each, and only 50 were distributed to each trough. Diet, rate of feeding, temperature, period of treatment, strain of bacterium, volume of inoculum, and method of infection were the same as for the first trial. Because the fish were larger, the relative turbidity of the suspension of the bacterium was increased to McFarland Standard No. 4 or No. 5. Fourteen days passed before the disease organism could be detected in the kidneys of all fish. Treatment with drugs was started at that time.

Erythromycin was included in this trial, because of the promise it showed in the first trial. The rate of dosage was increased, however, from 40 milligrams to 100 milligrams per kilogram of fish (Table 3).

TABLE 3.—*Mortality of eastern brook trout in the second trial of drugs used for a 21-day period of experimental therapy of kidney disease*

Observations terminated	Drugs	Daily dosage per kilogram of fish	Percentage mortality
44 days after therapy	2-acetylamino-5-nitrothiazole	40 milligrams	65.0
44 days after therapy	2-phenoxyethanol	200 milligrams	78.0
80 days after therapy	penicillin, sodium G	75 milligrams	60.0
80 days after therapy	sulfamethoxypyridazine	200 milligrams	44.0
80 days after therapy	sulisoxazole	200 milligrams	74.0
80 days after therapy	none	none	82.5
207 days after therapy	erythromycin, crystalline base	100 milligrams	47.0
207 days after therapy	none	none	3.0[2]

[2]Cause of death was not determined.

Sulfamethoxpyridazine, a sulfonamide capable of maintaining high tissue levels and a rather low rate of excretion in man (Nichols, Jones, and Finland, 1956), was included in the trial even though it had not been tested *in vitro*.

Mortality from all troughs was regularly examined by gram-stained smears of kidneys in order to determine the cause of death. At termination, fish which remained in the troughs of uninoculated controls and those which had been fed erythromycin were examined both by gram-stained smear and by inoculation of the modified Mueller Hinton medium.

Results. Fish which had been given 2-acetylamino-5-nitrothiazole and 2-phenoxyethanol were discarded 44 days after treatment was stopped, because there were no beneficial effects (Figure 2). Most of the other lots were discarded 36 days later, and only the uninoculated controls and those which had received erythromycin were kept an additional 125 days or for a total of 207 days after treatment was stopped.

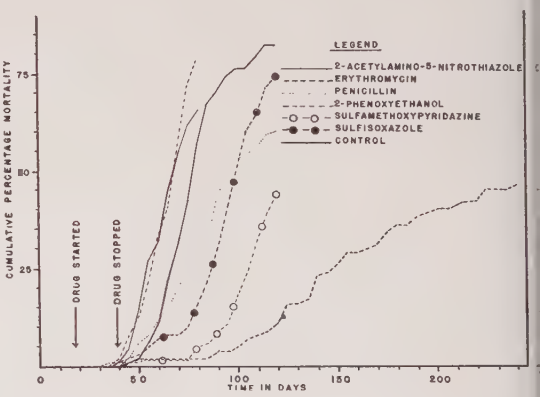

FIGURE 2.—Comparison of therapeutic effect of six drugs administered to eastern brook trout experimentally infected with kidney disease.

Mortality due to kidney disease began almost immediately after therapy in those lots which had been treated with 2-acetylamino-5-nitrothiazole, 2-phenoxyethanol, and penicillin (Figure 2). The effect of sulfisoxazole lasted only a little longer; kidney-disease mortality recurred about a week after treatment stopped.

Trout which had been fed sulfamethoxypridazine went 35 days before mortality began anew. Moreover, the rate of mortality indicated most if not all fish were still infected when observations were terminated. Erythromycin-fed fish were the last to show kidney-disease mortality. The rate of mortality was low in this lot, and the kidney disease bacterium could be found in only two of the 51 fish which remained (two fish were not accounted for). As nearly as could be determined, about half of the fish which received erythromycin were cured.

CONCLUSIONS AND RECOMMENDATIONS

1. Under the conditions of the experiment erythromycin was the most effective therapeutic agent for the treatment of kidney disease in eastern brook trout. It is likely that it also will be effective for treating this disease in other salmonids. Recommended dosage is at least 100 milligrams per kilogram of fish per day (4.5 grams per 100 pounds of fish) for 21 days.

Erythromycin is used in veterinary medicine, and it is one of the cheapest antibiotics available (about 15 cents per gram in 1958). Its use for the treatment of kidney disease in fish will, however, be expensive. Since the average value of trout is estimated to be about $1.00 per pound (Tunison, 1957), therapy with erythromycin would cost about 14 percent of the fishes' value. It is significant, however, that treatment of the disease with erythromycin resulted in about one-half the fish being cured. In contrast, 82.5 percent of the untreated fish died during the time of observation, and undoubtedly the balance would have died had they been kept longer.

2. Although treatment with erythromycin is expensive, the probability is that lasting benefit can be obtained in many of the fish and that fair value can be derived from the investment. All reports show a similar statement cannot be made for the sulfanomides which have thus far been used to treat kidney disease. Sulfamethoxypyridazine proved significantly better than sulfisoxazole and may represent the therapeutic superiority of the most recently synthesized sulfonamides. On the other hand, the demonstrated capacity of most strains of the bacterium to grow to a limited extent *in vitro* in the presence of the sulfonamides used may well reflect an inherent ability to tolerate this group of drugs.

3. Additional trials with penicillin may prove worthwhile. Penicillin G proved somewhat beneficial in experimental therapy of kidney disease. Better results might be obtained with penicillin V which is a comparatively new form of this antibiotic. It can be effectively administered orally; it is rapidly absorbed by humans, and it maintains high levels of concentration in tissues.

4. Snieszko and Griffin (1954) and Ordal and Earp (1956) found the kidney disease bacterium intracellularly as well as extracellularly. While within cells of the host fish, the bactrium is not exposed to the effect of therapeutic agents. Thus, if the bacterium exists intracellularly at the time therapy is stopped it will probably be able to incite a return of apparent infection. Until other data are available it is recommended there be no reduction in the 21-day period of treatment.

ACKNOWLEDGEMENTS

Drs. G. L. Hoffman, R. E. Lennon, and S. F. Snieszko reviewed the manuscript. Dr. Snieszko suggested the study and was freely consulted during its progress.

Bacterial strains from Washington and Oregon were kindly furnished by Dr. E. J. Ordal. Mr. R. Fielding isolated the strains from Chatahoochee, Ga., and Walhalla, S. C. Mr. Jimmy Camper supplied the Pisgah Forest, N. C., strain, and Mr. Ray Lane the Cortland, N. Y., strain. The Crawford, Nebr., strain was obtained through the cooperation of Mr. Dick Schultz. The strain now designated Leetown, W. Va., was originally obtained from Mr. Henry Delisle at Berlin, N. H. The bacterium was propagated in susceptible fishes for several years at the Eastern Fish Disease Laboratory by Dr. S. F. Snieszko and C. E. Dunbar. It was isolated on an artificial medium shortly before the study began.

The following companies furnished the antimicrobial substances used in this work: *Eaton Laboratories,* Norwich, New York—Furoxone(R), brand of furazolidone, Furacin(R), brand of nitrofurazone. *American Cyanamid Co.,* Lederle Laboratories Div., New York, N. Y.—tetracycline HCl, Kynex(R), brand of sulfamethoxypyridazine. *The Upjohn Company,* Kalamazoo, Michigan—novobiocin, erythromycin, sodium penicillin G, filipin. *Charles Pfizer and Co., Inc.,* Terre Haute, Indiana — Magnamycin(R) sulphate, brand of carbomycin. *Merck and Company,* Rahway, New Jersey—2-acetylamino 5-nitrothiazole, candicidin, fungichromin, eulicin, cycloserine; and *Sterling Drug Co.,* Rensselaer, New York—thiocymetin.

LITERATURE CITED

Allison, Leonard N. 1958. Multiple sulfa therapy of kidney disease among brook trout. Prog. Fish-Cult., Vol. 20, No. 2, pp. 66-68.

Deuel, Charles R., David C. Haskell, Donald R. Brockway, and O. R. Kingsbury. 1952. The New York state fish hatchery feeding chart. N. Y. State Conservation Dept., Fish. Res. Bull., No. 3, 3rd Ed., 61 pp.

Earp, B. J., C. H. Ellis, and E. J. Ordal. 1953. Kidney disease in young salmon. State of Wash., Dept. of Fisheries, Spec. Rpt. Series, No. 1, 74 pp.

Nichols, Roger L., Wilfred F. Jones Jr., and Maxwell Finland. 1956. Sulfamethoxypyridazine: preliminary observations on absorption and excretion of a new, long-acting antibacterial sulfonamide. Proc. Soc. Exp. Biol. Med., Vol. 92, pp. 637-640.

ORDAL, E. J., AND B. J. EARP. 1956. Cultivation and transmission of etiological agent of kidney disease in salmonid fishes. Proc. Soc. Exp. Biol. Med., Vol. 92, pp. 85-88.

RUCKER, R. R., A. F. BERNIER, W. J. WHIPPLE, AND R. E. BURROWS. 1951. Sulfadiazine for kidney disease. Prog. Fish-Cult., Vol. 13, No. 3, pp. 135-137.

SNIESZKO, S. F. AND PHILLIP J. GRIFFIN. 195 Kidney disease in brook trout and its treatme Prog. Fish-Cult., Vol. 17, No. 1, pp. 3-13.

TUNISON, A. V. 1957. Methods for determining t efficiency of production in the trout hatche Prog. Fish-Cult., Vol. 19, No. 2, pp. 51-57.

TUNISON, A. V., A. M. PHILLIPS, E. O. RODGE C. R. MITCHELL, AND C. M. MCCAY. 19 Cortland hatchery report, No. 7, New Yo State Conservation Dept., 23 pp.

Food Conversion and Growth Rates for Largemouth and Smallmouth Bass in Laboratory Aquaria

Wells E. Williams
Department of Natural Science, Michigan State University, East Lansing, Michigan

ABSTRACT

A laboratory and feeding experiment measuring the food conversion and growth rates of five largemouth bass (*Micropterus salmoides*) ranging in length from 117 to 312 millimeters (4.6 to 12.3 inches) and sixteen smallmouth bass (*Micropterus dolomieu*) ranging in length from 83 to 202 millimeters (3.3 to 7.9 inches) gave average food conversion values of 4.5 for the smallmouth bass, and 3.8 for the largemouth bass when an excess of small, live fish were fed, and average aquarium temperature was 70.3 degrees F. Individual bass consumed from 2.5 to 13.3 percent of their initial body weight daily, with highest consumption usually by the smaller bass. Average daily increase in weight in proportion to initial weight varied considerably, but was also greatest for the smaller fish.

EXPERIMENTAL PROCEDURES

Experimental feeding was conducted in the laboratory of the Department of Fisheries and Wildlife at Michigan State University for a period of fourteen weeks, beginning December 1, 1953, and ending March 9, 1954. Sixteen smallmouth bass (*Micropterus dolomieu*) and five largemouth bass (*Micropterus salmoides*) were collected from the Red Cedar and Looking Glass Rivers near East Lansing. The five largemouth bass ranged in length from 117 to 312 millimeters (4.6 to 12.3 inches), and the sixteen smallmouth bass ranged in length from 83 to 202 millimeters (3.3 to 7.9 inches). Individual weights ranged from 19 to 454 grams for the largemouth bass and from 4 to 112 grams for the smallmouth bass (Table 1).

The captured bass were placed in glass-sided aquaria in the laboratory, and were fed approximately all the food they were able to consume for one week before the feeding program began. During this "adjustment period", weights of forage species fed were not recorded. The aquaria were divided into individual compartments by glass "spacer" plates held in place by means of short lengths of rubber tubing, so placed as to allow oxygen diffusion to all compartments. The individual compartments were of approximately 12.5 gallons in capacity for the smallmouth bass, and 4 gallons for the largemouth bass, with the exception that the largest bass in the sample was placed in a large, museum-type display aquarium having a capacity of 100 gallons. The spacers were installed to prevent cannibalism and to allow individual observation and feeding of the experimental bass. All aquaria were covered to prevent introduction of foreign materials and escape of fish by leaping. One aerating hose attached to a central compressor was placed in an end compartment of each aquarium. Water was added only when necessary to keep aquaria filled to capacity, and once each week, excrement and accumulated materials were siphoned out.

Individual bass were weighed in water to the nearest 0.1 gram at the beginning of the experiment, three times during its course, and again at its conclusion. Bass weighed were first anesthetized in a one-percent solution (by weight) of ethyl ether. Four bass died while under the anesthesia; data for these bass were recorded up to the time of death, and are included in the results. Forage species were also weighed in water to the nearest 0.1 gram. Length measurements in millimeters were obtained by the use of an ordinary fish-measuring board.

Bass were fed live forage fish twice daily, at 7:30 a.m. and 5:30 p.m. Excess forage fish not consumed in subsequent feeding periods were removed, weighed, and subtracted from the record. It was observed during feedings that the larger bass consistently refused small prey items and often would not feed until larger food species were introduced. This is in agreement with the conclusion reached by Lagler and Kruse (1953) from data taken

[1]Portion of a Master's thesis submitted to the Graduate Faculty of Michigan State University, June, 1954.

from a similar study using fewer fish. Water temperature in degrees Fahrenheit was recorded at each feeding. During the experimental period, water temperature ranged from 67.0 to 77.0 degrees F.

Forage fishes were held in cement tanks in the laboratory. The species used included the brook stickleback, *Eucalia inconstans;* the fathead minnow, *Pimephales promelas;* northern redbelly dace, *Chrosomus eos;* the common bluegill, *Lepomis macrochirus;* the golden shiner, *Notemigonus crysoleucas auratus;* and three species of the genus *Notropis.* All forage fish were of sizes small enough to be eaten by bass to which they were fed.

FOOD CONVERSION

At a mean water temperature of 70.3 degrees F. (from a low of 67.0 to a high of 77.0 degrees F. during the feeding period) the average food conversion value for smallmouth bass was 4.5, and that for the largemouth bass 3.8 (Table 1). These mean values are somewhat less than the ratio of 5 to 1 suggested by Richardson (1921) for fish living primarily on animal food. Individual bass varied considerably in the ability to convert food to flesh; conversions ranged from 2.1 to 6.9, with a tendency being shown for smaller bass to have lower (more efficient) food conversion ratios. This relationship was not regular enough to admit statistical verification.

The average daily food consumption for all bass studied was 4.3 percent of the initial body weight. This value is slightly more than the optimum rate of 4 percent found by Thompson (1941) for largemouth bass ranging in size from fingerlings to one pound in weight. Prather (1951) stated that daily feedings of more than 5 percent of initial body weight to largemouth bass yearlings were poorly utilized; the present study clearly indicated that efficient conversions (ratios below 3.0) were obtained by feeding from 2.5 to 13.3 percent of the initial body weight daily. It was evident (Table 1) that food requirements of the smaller individuals were greater than for larger fish.

TABLE 1.—*Weight data, feeding rates, food conversion, and growth rates of largemouth and smallmouth bass*

Species	Initial weight (grams)	Final weight (grams)	Weight gained (grams)	Feeding period (days)	Food consumed (grams)	Percentage initial weight consumed per day	Percentage initial weight gained per day	Conversion rate	Daily instantaneous growth rate
Largemouth bass	19	44	25	98	57	3.1	1.4	2.3	0.0085
	20	75	55	98	129	6.6	2.8	2.3	0.0134
	22	72	50	98	107	5.0	2.3	2.1	0.0120
	27	38	11	63	63	6.9	1.2	5.7	0.0054
	464	526	62	62	409	2.0	0.3	6.6	0.0018
							Average:	3.8	
Smallmouth bass	4	24	20	98	52	13.3	5.1	2.6	0.0182
	5	25	20	98	56	11.4	4.1	2.8	0.0164
	8	22	14	98	51	6.5	1.8	3.6	0.0103
	13	33	20	98	82	6.4	1.5	4.1	0.0095
	22	57	35	98	107	6.5	1.6	4.0	0.0097
	24	31	7	52	31	2.0	0.4	4.4	0.0049
	26	33	7	98	55	2.2	0.3	7.9	0.0024
	31	46	15	98	79	2.6	0.5	5.2	0.0040
	34	49	15	98	98	2.9	0.4	6.5	0.0037
	39	66	27	98	120	3.1	0.7	4.4	0.0053
	40	55	15	98	98	2.5	0.4	6.5	0.0032
	55	98	43	98	112	2.1	0.8	2.6	0.0058
	56	84	30	98	154	2.8	0.5	5.5	0.0041
	60	113	53	98	198	3.4	0.9	3.7	0.0078
	111	144	33	34	121	3.2	0.9	3.7	0.0079
	112	177	65	98	309	2.8	0.6	4.8	0.0046
							Average:	4.5	

WEIGHT AND LENGTH GAINS

Total weight gains for individual bass varied widely (Table 1), with the largemouth bass gaining more weight than smallmouth bass of comparable size. One smallmouth bass (the smallest in the sample) gained five times its starting weight during the 14-week period. Average daily length increases ranged from 0.0 to 0.6 millimeters (Table 2), showing an average daily increment of 0.3 millimeters for the entire sample.

Instantaneous rates, expressed as the natural logarithms of the quotients obtained by dividing the terminal or final weight by the initial or starting weight of bass studied were used to represent the relative growth rates (by weight) of fish in the sample. The relationship is expressed by the formula

$$i = \log_e \frac{Y_t}{Y_o}$$

where i is the instantaneous rate of growth, Y_t is the terminal or final weight, and Y_o the initial weight. The values for i were divided by the number of days in the feeding period for individual bass to give *daily* instantaneous growth rates (Table 1).

ACKNOWLEDGMENTS

The author wishes to express his sincere thanks to Dr. Peter I. Tack, under whose able supervision this investigation was undertaken. He is also greatly indebted to Dr. Robert C. Ball for his valuable suggestions and guidance, to Dr. E. W. Roelofs, for his critical reading of the manuscript, and to Messrs. Robert Chapoton who aided in collecting bass, and Jack Hernly who provided many of the forage fish.

TABLE 2.—*Length*[1] *data for bass*

Species	Initial length	Terminal length	Length gain	Number of days for length gain	Daily length gain
Largemouth bass	117	117	60	98	0.6
	121	174	53	98	0.5
	124	134	10	63	0.2
	133	151	18	98	0.2
	312	312	0	62	0.0
Smallmouth bass	83	127	44	98	0.4
	84	126	42	98	0.4
	84	120	36	98	0.4
	109	149	40	98	0.4
	123	139	16	52	0.2
	127	141	14	98	0.1
	127	147	20	98	0.2
	137	156	19	98	0.2
	142	156	14	98	0.1
	150	174	24	98	0.2
	152	160	8	98	0.1
	160	185	25	98	0.3
	167	202	35	98	0.4
	169	207	38	98	0.4
	192	220	28	98	0.3
	202	207	5	34	0.2

[1] Lengths are given as total length in millimeters.

LITERATURE CITED

KINGSBURY, OLIVER R. AND WILLIAM F. ROYCE. 1935. Propagation of smallmouth bass in troughs at South Otselic bass hatchery. Trans. Am. Fish. Soc., Vol. 65, pp. 309-312.

LAGLER, KARL F. AND THOMAS E. KRUSE. 1953. Food conversion in black basses of the genus Micropterus. Jour. Wildlife Mgmt., Vol. 17, pp. 219-221.

PRATHER, E. E. 1951. Efficiency of food conversion by young largemouth bass *Micropterus salmoides* (Lacepede). Trans. Am. Fish. Soc., Vol. 80, pp. 154-157.

RICHARDSON, R. E. 1921. The small bottom and shore fauna of the middle and lower Illinois River and its connecting lakes, Chillicothe to Grafton: its evaluation; its sources of food supply; and its relation to the fishery. Bull. Ill. Nat. Hist. Sur., Vol. 13, pp. 359-522.

THOMPSON, DAVID H. 1941. The fish production of inland streams and lakes. Symposium on Hydrobiology, Univ. Wis. Press, Madison, 1940, pp. 206-217.

Observations on a Lernaean Parasite of Freshwater Fishes

A. James Haley and Howard E. Winn
Zoology Department, University of Maryland, College Park, Maryland

An examination of fish collected from Smith Pond, College Park, Maryland in July, 1957 revealed that several species were heavily infected with the parasitic copeopd, *Lernaea cyprinacea* Linnaeus. Additional collections were made throughout the summer and early fall in order to ascertain the host distribution of the parasite, and the incidence and intensity of infection. The purpose of this paper is to report the results of this survey, as well as some preliminary observations on the life history of the parasite and gross pathology of the infection.

RESULTS OF THE SURVEY

From July 6 through October 5, 1957, 883 fish representing 6 families, 11 genera and 14 species were seined from Smith Pond. Of these, 265 (30.0 per cent) of the fish harbored one or more *L. cyprinacea* (Table 1). Representatives of 9 species were parasitized, but little or no significance can be accorded the negative findings in the other five species because of the few individuals examined. The incidence of infection was higher in members of the Cyprinidae and Catostomidae than in other groups.

The most commonly infected species, based on 100 or more specimens, was the golden shiner, *Notemigonus crysoleucas*. This species also consistently harbored the greatest number of adult copepods per individual. The number of adult *L. cyprinacea* on 101 *N. crysoleucas* ranged from 1 to 43 with a mean of 3.4 copepods per fish. The mean copepod burden was higher in July and early August (6.0), however, than in the late summer and early fall (1.2).

Two hundred seven (33.8 per cent) of the 613 fish upon which no *L. cyprinacea* were found, had one or more lesions that were identical with those found associated with the attachment of the copepod. The presence of these lesions was regarded as evidence of a history of infection with the parasite. The number of fish with *L. cyprinacea*, plus those with lesions only, was 472 or 53.6 per cent of the total number examined.

DESCRIPTION OF THE INFECTION

All of the lernaeids that were found attached to the body surfaces of the fish were maturing or adult females. Twenty mature specimens ranged in length from about 6 to 11 millimeters with a mean of 8.6 millimeters, exclusive of the egg sacs. The anterior end of the parasite, with its four characteristic cephalothoracic horns, was deeply embedded in the flesh of the host. The tissue at the site of attachment was hemorrhagic, spongy and often necrotic. The lesions were fungus-free and varied from about 1 to 4 millimeters in diameter.

Adult female copepods were found embedded in all of the external body surfaces particularly near the base of the fins (Figure

Table 1.—*Incidence of L. cyprinacea in fishes collected at Smith Pond, College Park, Maryland from July 6 through October 5, 1957*

Host	Number examined	Number infected	Per cent infected
Anguillidae			
Anguilla rostrata	9	0	0
Catostomidae			
Catostomus commersoni	175	40	22.3
Erimyzon oblongus	10	5	50.
Centrarchidae			
Lepomis gibbosus	119	10	8.
L. macrochirus	42	2	4.
Micropterus salmoides	21	0	0
Cyprinidae			
Cyprinus carpio	2	2	.....
Notemigonus crysoleucas	463	192	41.
Notropis analostanus	11	7	63.
N. cornutus	1	0	.....
N. hudsonius	24	5	20.
Rhinichthys atratulus	1	0	.....
Esocidae			
Esox niger	3	0	.....
Umbridae			
Umbra pygmaea	1	1	.....
Total	883	265	30.

[1] This work was supported by research grant E-1619 from the Institute of Allergy and Infectious Diseases, National Institutes of Health, U. S. Public Health Service.

FIGURE 1.—*Lernaea cyprinacea;* adult females attached to and around the dorsal fin of *Notemigonus crysoleucas.*

. The area around the dorsal fin was infected out twice as often as that around the other ns. On occasion the parasites were found ached near the eyes, in the nares, about the ws and in the buccal cavity (Figure 2).

According to Wilson (1918) the life history members of the genus *Lernaea* includes a mporary host for the copepodid stages, and definitive host for the adult females. In the esent study the gills of 84 fish were examined r copepodid larvae with the following results: *Notemigonus crysoleucas* (30 examined 1 with copepodid larvae), *Cyprinus carpio* -2), *Erimyzon oblongus* (6-2), *Catostomus nmersoni* (19-1), *Notropis hudsonius* (17-, *Notropis cornutus* (3-0), *Rhinichthys atratus* (1-0), *Umbra pygmaea* (1-0), *Lepomis obosus* (3-0), *Anguilla rostrata* (1-0) and *ox niger* (1-0). Copepodids were much re numerous on the gills of *C. carpio* and *E. oblongus* than on the gills of *N. crysoleucas* and *C. commersoni.* These data suggest that *L. cyprinacea* may be capable of completing its life cycle by utilizing one as well as two host species. Further work on this point and other aspects of the host relationships of *L. cyprinacea* are in progress by the first author.

FIGURE 2.—*Lernaea cyprinacea;* adult females attached to the head region of *Notemigonus crysoleucas.*

ACKNOWLEDGEMENTS

The authors wish to thank Dr. David Causey of the University of Arkansas for confirming the identification of *L. cyprinacea.* Sincere appreciation is expressed also to Mr. Jack Stout for aid in collecting the fish, and to Maryland State Game Wardens John Law and Charles Garner for their encouragement and assistance.

LITERATURE CITED

WILSON, C. B. 1918. The economic relations, anatomy and life history of the genus *Lernaea.* Bull. U. S. Bur. Fish. 35 (1915-1916):163-198.

A New Microsporidan Parasite from the Pink Shrimp (Penaeus duorarum)[1]

EDWIN S. IVERSEN AND RAYMOND B. MANNING
The Marine Laboratory, University of Miami, Miami, Florida

ABSTRACT

A new species of microsporidian (sporozoan) parasite in the musculature of the pink shrimp *Penaeus duorarum* from three locations in south Florida is described. The name *Thelohania duorara* n. sp. is suggested for this parasite which causes a milky white color in pink shrimp. The ovoid spores measured 5.4 by 3.6 microns and had a polar filament of uniform diameter and 38 microns in length.

INTRODUCTION

Shrimp dealers and fishermen report finding specimens of "milk" or "cotton" shrimp in catches of pink shrimp, *Penaeus duorarum* Burkenroad, from south Florida. Since it has long been known that microsporidian (sporozoan) parasites cause this condition in Crustacea, it is not surprising to find this parasite in the pink shrimp. Closely related species of shrimp from Louisiana are also known to harbor these parasites. Sprague (1950) described two new species of Microsporidia from penaeid shrimp, *Nosema nelsoni,* present in the muscle tissue of the brown shrimp, *P. aztecus,* and *Thelohania penaei,* present in the reproductive organs of the white shrimp, *P. setiferus.* Further notes on crustaceans infected with these parasites in the Gulf of Mexico are given by Sprague (1954).

Also, Woodburn *et al.* (1957) discussed the occurrence of "cotton" shrimp from the west coast of Florida and the Tortugas shrimp grounds. They state, "Microscopic examination of these muscle tissues revealed numerous spores similar to those described for the microsporidian *Nosema nelsoni* Sprague, 1950. Living spores measured from 2.4 to 2.5 microns in length and from 1.4 to 1.5 microns in width."

Samples of obviously infected pink shrimp were collected from three locations in south Florida, Biscayne Bay, Florida Bay, and the Dry Tortugas shrimp fishing grounds. These samples, collected from 1956 to 1958, upon examination showed the presence of larger spores than those seen by Woodburn *et al.* (*op. cit.*). The spores observed by the writers belong to the genus *Thelohania,* because individual sporonts contained eight spores.

On the basis of the spore characteristics and the site of infection, the microsporidian which we observed in the pink shrimp is believed to be tentatively considered as a new species. The name *Thelohania duorara* n. sp. is suggested.

The authors wish to extend their thanks to the various members of the Fisheries staff of The Marine Laboratory, University of Miami, who have aided materially in the collection of material used in this study. The authors are also very grateful to Dr. Elmer R. Noble, University of California, Santa Barbara, and Dr. Victor Sprague, Ward's Natural Science Establishment, Monterey, California, for reviewing this manuscript. This work was done incidental to shrimp research supported at this laboratory by the Florida State Board of Conservation and the U. S. Fish and Wildlife Service.

MATERIAL AND METHODS

Three infected pink shrimp were obtained from the Dry Tortugas fishing grounds located about 30 miles northwest of Key West, Florida. Two of these specimens of about 135 millimeters, measured from the tip of the rostrum to the tip of the telson (total length), were collected during May 1957, and placed on ice for about 12 hours and then frozen. The third specimen, about 127 millimeters in length, was found dead in the trawl and was placed in 10 percent formalin shortly after capture.

Live pink shrimp of about 115 millimeters in total length were killed and fresh spores examined from collections made in Biscayne Bay in May, 1958, and Florida Bay in October, 1958.

Some of the recommended reagents and methods (Kudo, 1924) were used in an attempt to extrude the spore filaments. Among

[1]Contribution No. 225 from The Marine Laboratory, University of Miami.

these were hydrogen peroxide, acetic acid, hydrochloric acid, ether, iodine water, and mechanical pressure. None of the reagents seemed to accomplish the purpose, nor did slight to moderate amounts of mechanical pressure. However, when fresh spores were placed on plastic or glass slides and subjected to 1000-3000 pounds pressure on a Carver hydraulic press, a few extruded filaments were noted in the preparations.

DESCRIPTION OF *Thelohania duorara* n. sp.

The site of infection is in the musculature of the shrimp, where, in obviously infected shrimp, extremely large numbers of spores can be found. The muscle fibers of the body and even the legs of the shrimp appear milky white and slightly opaque when heavily infected. The other organs of the body appear to be free of infection. A microscopic study of the ovaries of the pink shrimp carried out at The Marine Laboratory involved examination of ovaries from all months of the year. Although numerous preparations were made no infection was noticed.

The spores of *T. duorara* are ovoid (Figure 1A). The spore membrane shows no striations. No polar capsules were noted. Some spores exhibit a rounded vacuole or clear space at the opposite end of the spore from the filament. The sporoplasm appears to be finely granulated and the polar filaments could not be observed inside the spore. Live spores measured 5.4 microns in length and 3.6 microns in width, based on 13 measurements. A few substantially larger spores were noted but were considered abnormal. Dimorphism of spore size in *Thelohania* has been reported. The larger spores are considered to be abnormal (Kudo, 1924). The polar filament was about 38 microns in length and was of uniform diameter throughout its length. Frozen spores measured 5.7 microns in length and 4.2 microns in width, based on only a few measurements. Spores from shrimp preserved in approximately 10 percent formalin were similar in size to frozen spores.

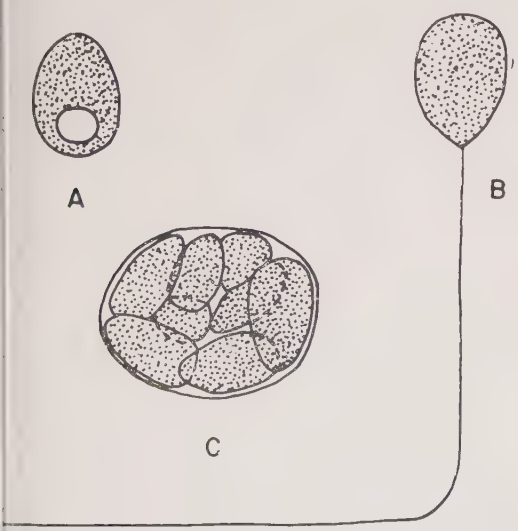

FIGURE 1.—*Thelohania duorara* n. sp.
A—Formalin-preserved spore showing vacuole (approximately x 2600).
B— Living spore with polar filament extruded (approximately x 2600).
C—A sporont containing spores (approximately x 1100).

The live sporonts are rounded (Figure 1C) and are about 11 microns in diameter. The eight spores are apparently surrounded by a thin transparent membrane.

T. duorara can be distinguished from *T. penaei,* the only other known member of this genus in penaeid shrimp, by its larger size and different site of infection. Since measurements of spores from both species were made from live material the sizes are readily comparable.

The average length of the majority of living spores of *T. penaei* is given by Sprague as approximately 4 microns in length and 2.2 microns in width. Living spores of *T. duorara* measured about 5.4 microns in length and 3.6 microns in width. Sprague, however, found that some of the spores were larger and these are within the range of *T. duorara,* but he made his identification on the basis of the smaller spores. The shape of the spores of *T. penaei* are pyriform; *T. duorara* differs by producing ovoid spores. There is apparently also a difference in the shape of the polar filaments of the two species. *T. penaei* has a filament consisting of two distinct portions: the proximal portion is relatively thick and uniform in size up to a short transitional zone where it suddenly tapers. The distal half is uniformly thin. The filament of *T. duorara* appears to be of uniform diameter throughout its length (Figure 1B).

The site of infection also differs in the two species, for *T. penaei* was found only in the ovaries of the white shrimp (Sprague, 1950) and the present species has been found infecting only the musculature of the pink shrimp.

A portion of musculature from the tail of a pink shrimp infected with *T. duorara* has been sent to the United States National Museum. It has received Catalogue Number 23604. A portion was also deposited in the reference collection of The Marine Laboratory; this portion has received UMML Number 1-47.

INFECTION RATE

Interviews with Key West fishermen and wholesale shrimp dealers suggest the heavily infected (markedly milk colored) pink shrimp occur rather infrequently in the catches. The most common answer to the question of how often "milk" shrimp are found was that one or two such individuals would be found in 2 or 3 hundred pounds of large shrimp (greater than 60 count per pound, heads off). Fishermen queried were those who culled the small shrimp from the catch and "headed" the large shrimp by hand on board the vessel. Field observations by staff members of The Marine Laboratory tend to confirm this infection rate. In connection with other studies in the Everglades Park area, samples of small shrimp (about 70-80 millimeters, total length) were taken throughout the year. These samples indicate a very low rate of infection for the shrimp from this estuarine area.

Woodburn *et al.* stated " . . . our work suggests that 'cotton shrimp' [presumably *P. duorarum*] are more common among the juveniles in the bays along the west coast of Florida than among the adults of the Tortugas area." However, their observations may have been made on *Nosema* rather than on *Thelohania,* for they made no reference to the latter genus. *Nosema* was not found by the present authors in infected *P. duorarum* from any of the three locations in south Florida.

Microscopic examination of many samples of shrimp tissue collected at all times of the year from different locations is required before useful data on the rate of infection can be obtained.

LITERATURE CITED

Kudo, Roksabro. 1924. A biological and taxonomic study of the Microsporidia. Illinois Biol. Monogr., Vol. 9, No. 23, 268 pp.

Sprague, Victor. 1950. Notes on three microsporidian parasites of decapod Crustacea of Louisiana coastal waters. Occ. Pap. Mar. Lab., La. Univ., No. 5, 8 pp.

———. 1954. Protozoa. Gulf of Mexico, its origin, waters, and marine life. U. S. Fish and Wildl. Serv., Fish. Bull. No. 89, p. 251.

Woodburn, K. D., Bonnie Eldred, Eugenie Clark, Robert F. Hutton and Robert M. Ingle. 1957. The live bait shrimp industry of the west coast of Florida (Cedar Keys to Naples). Fla. St. Bd. of Cons., Tech. Ser. No. 21, 33 pp.

The Known and Possible Role of Minerals in Trout Nutrition and Physiology

ARTHUR M. PHILLIPS, JR.
U. S. Fish and Wildlife Service, Cortland, New York

ABSTRACT

The known role of minerals in trout nutrition and physiology are discussed. It is pointed out that dissolved minerals in the water play an important part in the normal metabolism of the fish. A knowledge of mineral metabolism in higher animals has resulted in the rearing of more vigorous and healthy animals and the accumulation of such knowledge for fish should provide a sounder basis for both the rearing of hatchery fish and the management of natural waters.

Of all the materials in the animal body, minerals are the most difficult to study. Many minerals are required in such small quantities that it is almost impossible to compound diets or environments that are sufficiently free of the elements to allow critical studies. Knowledge of the roles of minerals in the bodies of higher animals is a relatively recent development. In fish the role of minerals is poorly understood.

Minerals are divided into two groups, major and trace. The major minerals are present in the body at fairly high levels and are needed by the body in a large continuous supply. The trace minerals are present in the body in small amounts and are supplied by the food or environment at very low levels. Both trace and major minerals are essential for life and the amounts of the minerals that are required are not an index of importance or necessity. Thus cobalt, a trace mineral required in very small amounts, is as necessary for life as calcium, a major mineral that is required in large amounts.

In trout, only iodine has been described as preventing a definite deficiency disease. A deficiency of iodine in trout diets results in the development of goiter as it does in the higher animals. Although only one mineral deficiency is recognized in trout, it must be assumed that all of the minerals required by the higher animals are also required by trout.

Mineral deficiency studies with fish are difficult because fish have two available sources, water and food. Standard techniques that have been developed for other species of animals are unsatisfactory for fish studies and progress has been slow. At present only sodium chloride is used as a constant supplement in trout diets and the salt is added primarily to bind the diet and not as a source of inorganic material for body metabolism.

In 1950 the Fish and Wildlife Service established facilities at the Cortland Laboratory, which are at present being operated by Mr. Henry A. Podoliak, that provided for the utilization of radio-active isotopes in mineral studies upon trout. By this effort, an entirely new field was opened for physiological studies upon fish. The first studies completed provided evidence that calcium was absorbed directly from the water by the fish without the necessity of the mineral being ingested. Subsequent studies have shown that in addition to calcium, phosphorus, cobalt, and most recently chloride, are also absorbed directly from the water. The earlier literature stated that blood chlorides increased when fish were placed in salt solutions but it was concluded that the salt did not enter the fish's body under normal conditions. The increase in blood chloride was attributed to the movement of water from the fish's body to the environment. Present studies show that chlorides are absorbed from the water by the fish's body. It must now be accepted that many of the elements may enter directly into the metabolic processes of the fish's body from the water. Ingestion is not necessary for this to occur. The absorption of minerals is not necessarily a function of drinking, since the path of entrance of the absorbed minerals has been mainly through the gills of the fish. These studies open the way to new

[1]Presented as part of symposium on "Future Fish Culture" at 88th Annual Meeting of the American Fisheries Society, Philadelphia, September 8, 1958.

approaches on growth and production of fish and survival of stocked fish in natural waters.

Since the initial studies at Cortland, several important conclusions have been reached. Among these conclusions are:

1. The amount of calcium absorbed from the water varies with the amount of calcium present in the diet. Low dietary calcium results in more calcium being taken from the water and high dietary calcium reduces the amount of calcium absorbed from the water.

2. The amount of calcium in the water affects the amount of calcium absorbed from the food. More calcium is absorbed from food when 5 p.p.m. calcium is present in the water than is absorbed from the food by fish held in water containing 50 p.p.m. calcium.

3. Phosphorus is absorbed from the water in proportion to the amount present in the water. Not as much structural use of dissolved phosphorus was found as was found for dissolved calcium. Phosphorus fertilization of the water resulted in an increased utilization of dissolved calcium by brook trout. Phosphorus fertilization of the water thus directly benefited the fish. Most conclusions upon phosphorus fertilization in past experiments have been judged solely on the basis of the effect upon the production of food for the fish.

4. In the diet, a ratio of 1 part of phosphorus to 1 part of calcium was found the most effective for efficient utilization of the minerals.

5. The osmo-regulatory effect of the calcium ion in trout metabolism has been confirmed. Krogh (1939) stated in his book *Osmotic Regulation in Aquatic Animals* that calcium had an osmo-regulatory effect upon fish. Apparently this information has been forgotten in the intervening years. Present studies have shown that trout placed from high calcium waters into low calcium waters showed a marked increase in their metabolic rate. A copious supply of other minerals did not affect this alteration of metabolism. In low calcium waters the metabolism of the fish increases to actively oppose changes in blood concentration. It is interesting to speculate the effect of the transfer of fish from hatcheries supplied with high calcium waters to low calcium waters in nature.

The poor survival obtained in some stocking programs may be a function of the mineral content of the stocked waters. In low calcium waters, trout accustomed to high calcium waters may have to expend energy for osmo-regulatory purposes. Even an abundance of natural food might not supply the essential calcium. The ingested food must, under these circumstances, then furnish energy for the increased catabolic activity because of an upset in basal metabolism due to a lack of calcium. Poor growth, low survival rates, and inefficient utilization of food (conversion) may result.

Since it is now known that at least some of the minerals are absorbed directly from the water by fish, it may be assumed that the basic physiology of the fish depends to some extent upon the presence of the minerals in the water. What are some of the possibilities of the role of minerals in the waters and foods of fishes?

As mentioned previously, fish transferred from hard water hatcheries to soft natural waters may have a survival problem. Other possibilities also present themselves concerning the role of minerals in fish management and husbandry.

There are areas in the country that cannot produce healthy cattle. Hay crops may appear normal but cattle will not grow in a satisfactory manner. In some of these areas fertilization of the pasture soil with a trace of cobalt results in economical rearing of healthy, vigorous cattle. Will the fertilization of fish pastures with certain trace minerals effect the growth and survival of these fish and result in increased yields per acre?

During a recent seminar on farm ponds, the statement was made that trace minerals were of no benefit in farm ponds. Of course this statement is in error for trace minerals are necessary for life itself. Perhaps the particular ponds referred to did not respond to fertilization with trace minerals because sufficient quantities were originally present. This does not mean that such fertilization would not be beneficial elsewhere. The minerals present in natural waters depend upon the minerals of the surrounding soil. Since soil composition varies from one area to another, the mineral content of the water may also vary. Work needs to be done to determine if natural water fertilization with trace minerals would be beneficial and economical.

The role of minerals in hatchery diets has been neglected. In higher animals the role of minerals is more thoroughly understood and diets are compounded to contain minimum required levels. Thus in areas deficient in some

of the minerals, the diets are supplemented to supply the missing elements. For example, in certain states, where the soil is deficient in iron, an iron solution is painted on the nipples of the mother pig to allow survival of the suckling and to prevent almost certain anemia. In areas near the Great Lakes, where the soil is lacking in iodine, city water supplies are often fortified with iodine to prevent goiter. More recently, areas deficient in fluorine have attempted to supply the missing element through the addition of fluorine to water supplies. In areas that lack manganese and magnesium in the soil, farm animal rations are supplemented to over-come the deficiency of the forage. The possibility of regional deficiency of minerals has not always been taken into consideration in rearing our hatchery fish or in managing our natural waters. Generally, waters of an area will suffer similar regional deficiencies as the soils of the area.

The establishment of the mineral requirements of higher animals has over-come many formerly incurable diseases. Dietary anemia was over-come in part with iron, cobalt, and copper; sub-normal bone development with calcium, phosphorus, fluorine, and magnesium; poor hair development with zinc; improper blood coagulation with calcium; and many problems of growth by a combination of several of the minerals. Mineral studies upon fish will surely be productive and such information should result in a more vigorous and healthy animal. Our imagination could run wild with speculation concerning the possibilities of fortifying hatchery diets and fertilizing natural waters. Minerals are not the panacea for all our troubles, but they have been neglected in our physiological and management studies.

SELECTED BIBLIOGRAPHY

Krogh, A. 1939. Osmotic regulation in aquatic animals. Cambridge University Press, London.

Maynard, L. A. 1956. Animal nutrition, 4th edition. McGraw Hill, New York.

Phillips, Arthur M. Jr., Floyd E. Lovelace, Henry A. Podoliak, Donald R. Brockway, and George C. Balzer. 1955. Fisheries Research bulletin No. 19. The nutrition of trout. Cortland Hatchery report number 24. New York Conservation Dept., Albany, New York.

Phillips, Arthur M. Jr., Henry A. Podoliak, Donald R. Brockway, and George C. Balzer, Jr. 1956. Fisheries Research bulletin No. 20. The nutrition of trout. Cortland Hatchery report number 25. New York Conser. Dept., Albany, New York.

Phillips, Arthur M. Jr., Henry A. Podoliak, Donald R. Brockway, and Ray R. Vaughn. 1957. Fisheries Research bulletin No. 21. The nutrition of trout. Cortland Hatchery report No. 26. New York Conser. Dept., Albany, New York.

Shohl, Alfred T. 1939. Mineral metabolism. Reinhold Publishing Corp., New York.

Underwood, E. J. 1956. Trace elements in human and animal nutrition. Academic Press, New York.

Muskellunge in Tennessee Streams

JOHN W. PARSONS

U. S. Bureau of Commercial Fisheries, Fish and Wildlife Service, Ann Arbor, Michigan

ABSTRACT

Muskellunge (*Esox masquinongy*) are known to inhabit 169 miles of rocky and fast-flowing streams on the Cumberland Plateau in East-Central Tennessee. These waters are usually clear (turbidity less than 5 p.p.m.) and slightly acid. Muskellunge in Tennessee streams grow an average of 5.8 inches per year but few fish live beyond 6 years of age. Male fish mature when about 22 inches long and 3 years old; females mature when about 25 inches long and 3 or 4 years old. Muskellunge spawn in April when water temperatures are near 50° F. Young fish are found in only 15 percent of the total habitat distance. Management of the muskellunge streams in Tennessee appears to be necessary to maintain the presently small muskellunge fishery.

INTRODUCTION

The muskellunge (*Esox masquinongy*) of Tennessee streams provides the southernmost muskellunge fishery in the United States. The muskellunge in Tennessee and the Ohio River drainage is often referred to as the Ohio muskellunge, *Esox masquinongy ohioensis;* however, there is no valid description of this subspecies. The muskellunge has attained great popularity as a sport fish in Tennessee although its range and abundance are limited. Recent decline in fishing success for this species led to the investigations upon which this report is based.

Muskellunge in Tennessee are silvery in color and marked with vertical bars. Fish 12-25 inches long have two rows of about 17 dark vertical bar markings on each side. These bars tend to interlock on the anterior portion of the fish and join near the posterior. Bar markings are less apparent on larger fish. Fins of muskellunge shorter than 4 inches are heavily tinted with orange, particularly the caudal fin and areas adjacent to the caudal peduncle. There is a black horizontal line through the eye. Fins on large fish are grayish although dorsal and caudal fins are often reddish.

DISTRIBUTION

Muskellunge are found in the headwater tributaries of the Tennessee and Cumberland Rivers on the Cumberland Plateau in East Central Tennessee. Eight streams in the Tennessee River drainage and 3 streams in the Cumberland River drainage provide 106 and 6 miles of muskellunge habitat respectively, fo a total of 169 miles (Table 1). So rarel are muskellunge taken from other waters i Tennessee that those captured are considere part of remnant populations. There are als 105 stream miles of muskellunge habitat tha have been destroyed by coal-mine wastes.

Observations of the muskellunge in Tenne see streams indicate that this fish has ver specific habitat requirements. Although man other streams have been exposed to natural in fluxes of muskellunge, the species does not oc cur there. There are, however, several stream on the Cumberland Plateau where natural fall have precluded upstream migration and pos sible establishment of this species.

DESCRIPTION OF STREAMS

Streams on the Cumberland Plateau wher muskellunge occur range from 790 to 173 feet above sea level. Bottom material in th larger streams consists of conglomerates an sandstone bedrock—sand or silt are presen only occasionally. The fast-flowing water cascade through deep canyons and gorges, an average stream gradients for several of th muskellunge streams range from 13 to 36 fee per mile.

The physical characteristics of Obed Rive are typical of most muskellunge streams. Thi river, surveyed by biologists of the Tennesse Game and Fish Commission, has 34 miles o fishing waters and at low water stage is abou one-third shoals. There are 394 pools averagin

TABLE 1.—*Stream mileage of existing and acid polluted muskellunge waters in Tennessee*

Drainage and stream	Miles of muskellunge habitat	Miles of polluted waters
Tennessee River		
Emory River	8	5
Crab Orchard Creek	9	.....
Rock Creek	6	.....
Obed River	34	.....
Clear Creek	.....	31
North Fork, Clear Creek	7	.....
Otter Creek	4	.....
Daddys Creek	35	.....
Byrds Creek	3	.....
Subtotal	106	36
Cumberland River		
South Fork, Cumberland River	6	.....
New River	.....	40
Clear Fork	42	.....
Crooked Creek	15	.....
East Fork, Obey River	.....	29
Subtotal	63	69
Total	169	105

½ acre in area and totalling 190.8 acres. The largest of these pools is 7 acres.

Headwaters of these streams, and some smaller tributaries, are often on the 'flats' of the Plateau, where stream gradient is low. In these areas, stream bottoms often consist of slightly shifting sand and silt. Waters in the streams are almost always clear (turbidity less than 5 p.p.m.) except for brief periods after unusually heavy rains. Total alkalinity is usually between 10 and 20 p.p.m. and pH between 6.8 to 7.0.

ASSOCIATED SPECIES OF FISH

Standing crops of fish in muskellunge streams, determined by sampling fish with the use of rotenone, range from about 60 to 100 pounds per acre. Principal native species are smallmouth bass, *Micropterus dolomieu;* rock bass, *Ambloplites rupestris;* longear sunfish, *Lepomis megalotis;* and hogsucker, *Hypentelium nigricans.* In some streams, largemouth bass, *Micropterus salmoides,* and bluegill, *Lepomis macrochirus,* have been introduced. Golden redhorse, *Moxostoma erythrurum,* and black redhorse, *Moxostoma duquesnei,* are abundant in some parts of the larger streams. Many carp, *Cyprinus carpio,* smallmouth buffalo, *Ictiobus bubalus,* and gizzard shad, *Dorosoma cepedianum,* have migrated into several streams from a large downstream impoundment.[1]

MATERIALS AND METHODS

Muskellunge examined from 1950 through 1955 were collected by hoop net, trammel net, dip net, angling, and with the use of cresol, rotenone, and electric seine.

Most small fish were collected by applying cresol to the water with a 2-gallon pressure pump. The spray mixture consisted of equal quantities of cresol[2] and water. Careful observance of the surfaces and edges of the pools usually revealed the location of young muskellunge (3 to 8 inches long) when waters were clear. With care, these fish could usually be approached within a few feet. The nozzle of the spray pump was then inserted into the water about 2 feet from and pointed in the direction of the fish, and the solution released to form a chemical cloud approximately 2 to 3 feet in diameter and 8 or 10 inches deep. Drift of the chemical and water soon enveloped the fish and within a few seconds, the fish exhibited distress and could be caught easily with a dip net. Yearling fish up to 18 inches in length have been captured by this method although the amount of chemical used was greater than for smaller fish. Pools in series as long as one-half mile were sometimes sampled with a single application of cresol. Rarely were fish killed by the cresol.

Seines and small-mesh dip nets were also used but in general they were far less efficient than cresol. Hoop nets were used for capturing larger muskellunge during spawning runs. Rock dams were constructed with apertures for placement of hoop nets which faced downstream. Fish up to 10 pounds were captured by this method. One trammel net was placed in a pool and fish driven into the net by flailing the water. This method proved effective for capture of large muskellunge as well as other species.

---

[1] Parsons, John W., 1953. A preliminary report on the fish population studies of Obed and Emory Rivers, Tennessee, 12 pp. [Mimeographed].

[2] Phenolic disinfectant (coefficient 30 F.D.A., *E. typhi*). Active ingredients; cresylic acids, coal tar neutral, soap, not over 10 percent water.

Length measurements were taken on 108 young-of-the-year muskellunge and lengths, weights, and scale samples were obtained from 33 larger fish. Many more muskellunge were captured, but unless conditions were ideal for measuring fish without injury, they were returned to the water without examination. Total and standard lengths, weights, sex, and stomach contents were recorded for all dead fish. Since the number of scale samples were inadequate for determining body-scale relationships, growth rates were computed from scale measurements by direct proportion. This method of growth calculation coupled with selectivity of sampling may largely account for the apparent decline in the growth of the older age groups. Scales were mounted dry between glass slides and read with a microprojector. Annuli were distinct.

GROWTH RATES

The growth in length of the muskellunge is nearly uniform during the first 4 years of life (Table 2). Greatest growth is during the second year, 7.6 inches (total length) and the yearly average is 5.8 inches. In comparison with growth rates in the northern United States and Canada, (Greely 1938, Hourston 1952, Ricker 1947, Schloemer 1938, Smith 1944, Van Oosten 1923), muskellunge in Tennessee grow slowly through the first 3 years and about average during later years.

TABLE 2.—*Calculated growth of the muskellunge in Tennessee*

[Collection from various Cumberland Plateau streams, 1950-1955]

Number of fish	Age group	Calculated total length (inches) at end of year					
		1	2	3	4	5	6
8	I	8.5	—	—	—	—	—
11	II	6.5	15.5	—	—	—	—
3	III	5.8	13.0	21.1	—	—	—
8	IV	5.8	12.1	18.9	25.0	—	—
2	V	5.4	13.6	19.2	26.4	30.1	—
1	VI	4.7	8.4	17.5	23.3	28.9	32.5
Average Total length (inches)[1]		6.7	13.7	19.2	25.2	29.7	32.5
Average annual increment		6.7	7.6	7.0	6.3	4.3	2.7
Sum of increments		6.7	14.3	21.3	27.6	31.9	34.6

[1] Conversion of total length to standard length for all age groups is 0.850.

Muskellunge studied in northern waters often reach an age of 12 years, and ages have been recorded up to 24 years. Few of the fish caught or observed in Tennessee streams weigh more than 5 pounds, were more than 30 inches long, or had reached their sixth year of life. The record fish for Tennessee, 46 inches and 22.5 pounds, was taken by angling from Emory River in 1947.

The growth of young muskellunge was determined from 108 fish collected from several streams on the Cumberland Plateau in 1952 and 1953. Young muskellunge grew from 2.4 to 6.0 inches long between June 1 and August 15 (Table 3). Cessation of growth after August 15 was a direct result of low water brought about by the extreme summer droughts of 1952 and 1953.

TABLE 3.—*Semi-monthly growth of young muskellunge in Tennessee streams*

Semi-monthly period	Number of fish	Total Length (inches)	
		Average	Range
June 1-15	2	2.4	.....
June 16-30	6	3.3	3.0-3.7
July 1-15	10	3.6	.....
July 16-30	2	4.6	4.2-5.0
Aug. 1-15	33	6.0	4.0-7.3
Aug. 16-31	41	5.9	4.7-8.5
Sept. 1--15	14	6.1	5.3-8.0

Thirty-one 6-inch muskellunge stocked in hatchery ponds in August, 1953, averaged 13.2 inches in length by January 15, 1954. One tagged 2.5-pound muskellunge stocked in Dale Hollow Reservoir in April 1953 weighed 7.25 pounds when recaptured by angling 11 months later.

MATURITY AND SPAWNING HABITS

Female muskellunge usually mature when 3 or 4 years old and approximately 25 inches long. Male fish usually mature when they are 3 years old and approximately 22 inches long.

Over a period of several years, the muskellunge spawned during April when water temperatures were near 50° F. Hoop-net catches in early 1952 and 1954 indicate an upstream pre-spawning movement of adult fish during late March and early April. One female had not yet spawned as late as April 23.

Muskellunge spawn successfully in Tennessee streams in shallow pools where accumulated organic material is abundant along the banks, in eddies, on the bottoms, or where aquatic vegetation, primarily *Potamogeton,* is common.

Stream gradient in these areas is usually much less and silt is more plentiful on the bottom than in other segments of the stream.

The muskellunge fishery in the 106 miles of streams tributary to the Tennessee River is dependent upon spawning success in 5 miles of Daddys Creek, 2 miles of Crab Orchard Creek, 2 miles of Emory River, 3 miles of Rock Creek, and 2 miles of Byrds Creek—a total of 14 miles or 12 percent of the total habitat.

The muskellunge fishery in the 63 miles of streams tributary to the Cumberland River is dependent upon spawning success in 8 miles of Crooked Creek and 3 miles of Clear Fork River—a total of 11 miles or 17 percent of the total habitat.

FOOD AND FEEDING HABITS

The muskellunge in Tennessee feed almost entirely upon fish. Little preference is shown by large muskellunge towards selecting any particular species of fish. An exception to the fish-eating tendencies of the muskellunge was demonstrated by the presence of eight 5-inch salamanders in the stomach of a 25-inch fish in February 1951.

Cannibalism is common to muskellunge of all sizes. One 28-inch muskellunge had a 16-inch muskellunge in its stomach. Occasionally large muskellunge were seen to attack other muskellunge voraciously.

The feeding habits of young-of-the-year muskellunge were observed closely in Crab Orchard and Rock Creeks during the summers of 1954 and 1955. The young muskellunge showed considerable patience, skill, and efficiency in capturing their prey. Usually the young fish remained motionless along the shore's edge, in patches of aquatic vegetation, beside submerged branches, or in patches of shade, only to dart out and capture a fish passing a few inches away. Almost all forage fish were seized by the middle, thoroughly chewed (as evidenced by scattering scales) and swallowed, usually head first.

The small muskellunge fed mostly in the upper 6 inches of the water. Occasionally, however, the young fish remained in a position vertical to the bottom as they hovered motionless over a small rock awaiting the eventual appearance of a hidden fish. Small muskellunge usually preferred pools with plentiful sunlight but often remained within the edge of the shaded portions of the pool. Small muskellunge often remained 15 minutes or longer in one position when forage fish were near. The concentration on potential prey sometimes was so intent the fish could be approached and touched with a stick before it showed alarm. This concentration may make young muskellunge subject to predation or cannibalism.

VULNERABILITY TO CAPTURE

That muskellunge are taken easily by angling was readily evident throughout the study. Large muskellunge usually remain throughout the summer in the same pool and once located by an angler, the fish eventually may be induced to take either an artificial lure or a minnow.

In 1953, seven marked muskellunge from 7 to 25 inches long were stocked in Dale Hollow Reservoir. Within 11 months, 3 of these fish were caught by angling. In April of the same year, 7 muskellunge, 17 to 32 inches long, were captured by hoop nets from Emory River. These fish were tagged and released in the same waters. Within 3 months 3 tags from these fish were turned in by fishermen. Of the total 14 marked fish, six (43 percent) were known to have been taken by fishermen.

MANAGEMENT

The investigations since 1950 make it apparent that adequate management must be undertaken soon in order to maintain the present muskellunge fishery in Tennessee. Several types of management that should be most successful are: acid coal mine waste control, transplants of young fish endangered by low water during extreme droughts, and the removal of several small dams that block adult muskellunge from spawning areas. In 1954, a 25-inch size limit was placed on the muskellunge to protect dwindling stocks.

A greatly expanded fishery may best be obtained by a well planned and executed propagation and stocking program. Several thousand young muskellunge have been stocked in Dale Hollow Reservoir in an attempt to establish a new fishery and reduce the abundance of gizzard shad by predation.

LITERATURE CITED

GREELY, JOHN R. 1938. Fishes of the area with annotated list. pp. 48-73 in A Biological Survey of the Allegheny and Chemung watersheds. Supp. 27th Ann. Rept., N. Y. Cons. Dept Biol. Survey No. 12.

HOURSTON, ALAN S. 1952. The food and growth of the maskinonge (*Esox masquinongy* Mitchell) in Canadian waters. J. Fish. Res. Bd. Can., Vol. 8, No. 5, Jan., pp. 347-368.

RICKER, WILLIAM E. 1947. Muskellunge. Ohio Cons. Bull. No. 11, p. 13.

SCHLOEMER, C. L. 1938. A second report on the growth of the muskellunge *Esox masquinongy immaculatus* (Garrard) in Wisconsin wate Trans. Wis. Acad. Sci. Arts, and Lett., Vol. 3 pp. 507-512.

SMITH, LLOYD JR. 1944. Minnesota fish fac Minn. Dept. of Cons. Bull. No. 7, pp 1-31.

VAN OOSTEN, JOHN. 1946. The pikes. U. S. Fi and Wildlife Serv., Fish. Leaflet 166, 6 p [Mimeographed].

Electro-Fishing for Small Fish in Lakes

LLOYD L. SMITH, JR., DONALD R. FRANKLIN AND ROBERT H. KRAMER

Department of Entomology and Economic Zoology, University of Minnesota, St. Paul 1, Minnesota

ABSTRACT

An electric seine for use on small fish in shallow water was designed to use interrupted direct current from a 2,500-watt direct current portable generator. An electronic circuit activated a relay in the seine supply circuit. A square wave with duty cycle of 0.50 to 0.90 was formed at frequencies of 20 to 300 per minute. Tests made in a webbing enclosure in a lake showed 240 interruptions per minute at 230 volts was most effective for catching fish. The seine was boat-mounted and embodied a double row of vertical electrodes. Electrotactic response was low but the seine is satisfactory if efficiency levels can be determined for water quality, orientation of operation, and other variables encountered in normal field work.

INTRODUCTION

Studies concerned with population trends, reproduction, and factors determining strength of year classes of game fishes in fresh-water lakes require quantitative sampling of small fish, especially those in their first year of life. Seines of various types have been generally used and some types of electrical gear have been tried, but no sampling method has been found entirely satisfactory. The problems usually arise from inability of the gear to work satisfactorily in weeds or on rough bottoms covered with obstructions. Electro-fishing gear using alternating curent has overcome some of these difficulties in stream sampling but its application to lakes has been limited by the fact that fish cannot be confined and therefore may avoid the fields before they can be narcotized.

Recent extensive use of direct current in fishing gear has shown that fish can be attracted to positive electrodes so that problems of avoidance are minimized. In order to explore some of the uses of direct current fishing devices in connection with small-fish sampling, an attempt has been made to develop an electrical seine design which would overcome operating difficulties of other gear and would sample small-fish populations in shallow water.

The requirements of such electrical fishing gear were recognized to be: (1) ability to capture unconfined fish; (2) sufficient field strength to capture very small fish; (3) portability; (4) durability and low maintenance; (5) capability of operation by two or three men; and (6) ability to fish where webbing seines could not be used.

The investigation reported below was carried out as part of Minnesota Dingell-Johnson Project F12R. Gear development was carried on in laboratories of the University of Minnesota, and the current interrupter was designed by L. T. Anderson of the Department of Electrical Engineering. Field trials were made in Lake George, Anoka County, Minnesota.

SOURCE OF POWER

A 230-volt, 2,500-watt direct current portable generator equipped with a rheostat in the field windings which provided control over a range of 70 to 230 volts was used as a power source. Previous investigations with direct current indicated that an interrupted flow was likely to be most useful for sampling gear. The California Marine Research Committee (1950) in experiments on smelt and sardine found that interruption frequencies of 3 to 4 per second were most effective to produce directional movement of fish. Haskell and Adelman (1955) confirmed these findings with small brown trout which responded best to a frequency of 1 interruption per second. Both experiments showed that the duty cycle of an interrupted current should be about 0.75. They also indicated that voltage levels capable of inducing electrotaxis were inversely related to the size of the fish.

Since no commercial device capable of interrupting an output of 2,500 watts with the

[1]Paper No. 3911, Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

desired frequency was available, a portable interrupter was designed. It consisted of a 3-tube electronic unit which controlled the operation of a large relay (Allen-Bradley, Model 202, Size 1) over a continuous range of frequencies from 20 per minute to 300 per minute. The resulting wave form was square, with a duty cycle which varied from 0.50 to 0.90 until a frequency of 120 per minute was reached. Above this frequency the duty cycle of each wave was 0.50.

The frequency of interruption and the duty cycle are controlled by the selection of various resistor-condensor combinations (Controls A, B, C, D, Figure 1). The "A" current supply for the relay control circuits is furnished by a 6-volt storage battery, and "B" supply by a Mallory VP6-325 vibrapack energized by this battery. The "C" supply consists of two 90-volt dry batteries wired in series and varied by Control "E".

The problem of arcing encountered by Tester (1952) who used both a mechanical disk-type interrupter and an electrode plunged in mercury was satisfactorily minimized by use a relay with four sets of points. Each side the seine supply circuit was passed throu two sets of points wired in series. At the c clusion of the experiments after more tha million operations, the points were still good condition. To facilitate portability protection the entire interrupter system enclosed in a plywod chest 26 by 20 by inches in size (Figure 2).

SEINE DESIGN

In order to evaluate the effectiveness various seine designs, short test sections of e type were fished inside an enclosure of ¼-i cotton webbing where known numbers of pe fingerlings and adult bluegills were confin This enclosure was 9 by 36 feet in size was suspended from steel stakes. A fish-ti seal was formed by folding the excess webb inward at the bottom and weighting it w iron pipe. Tests of design, voltage, and p frequency were made by pulling the test tions through the enclosure.

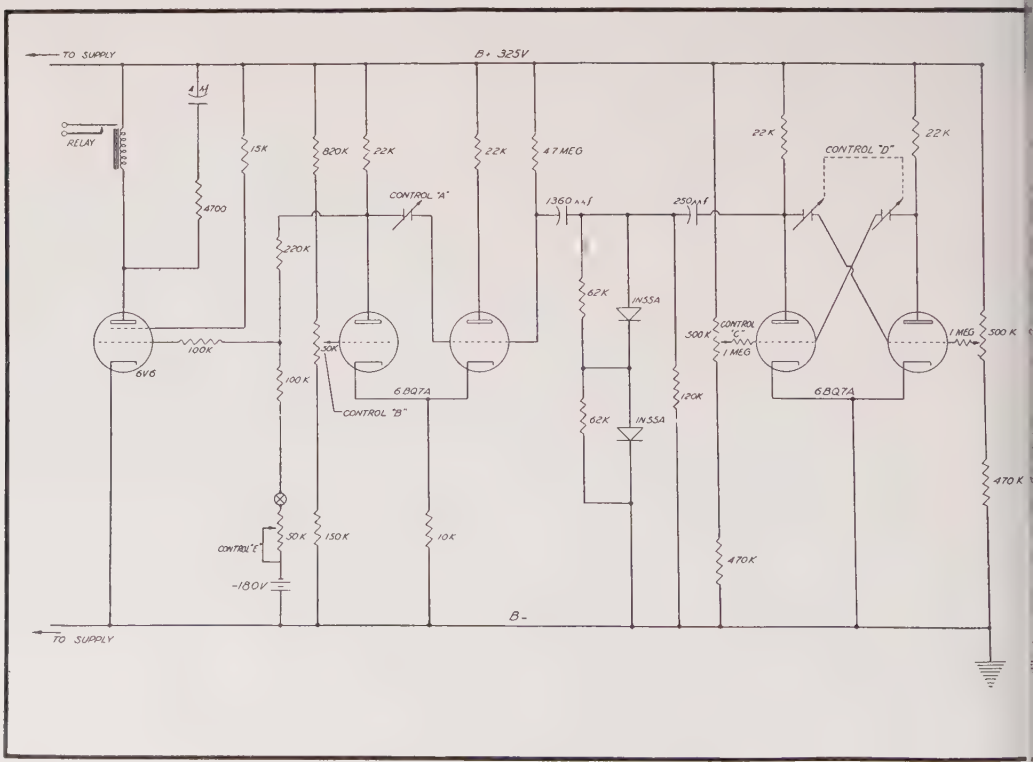

FIGURE 1. Schematic diagram of interrupter unit. Relay is Allen-Bradley Model 202, Size 1. Control "A" is a rotary switch with four selections of capacitance: 0.10, 0.35, 0.60, and 1.10 mfd. Control "D" is a two-deck rotary switch with four selections of capacitance on each deck: 0.20, 0.45, 0.70, and 1.20 mfd.

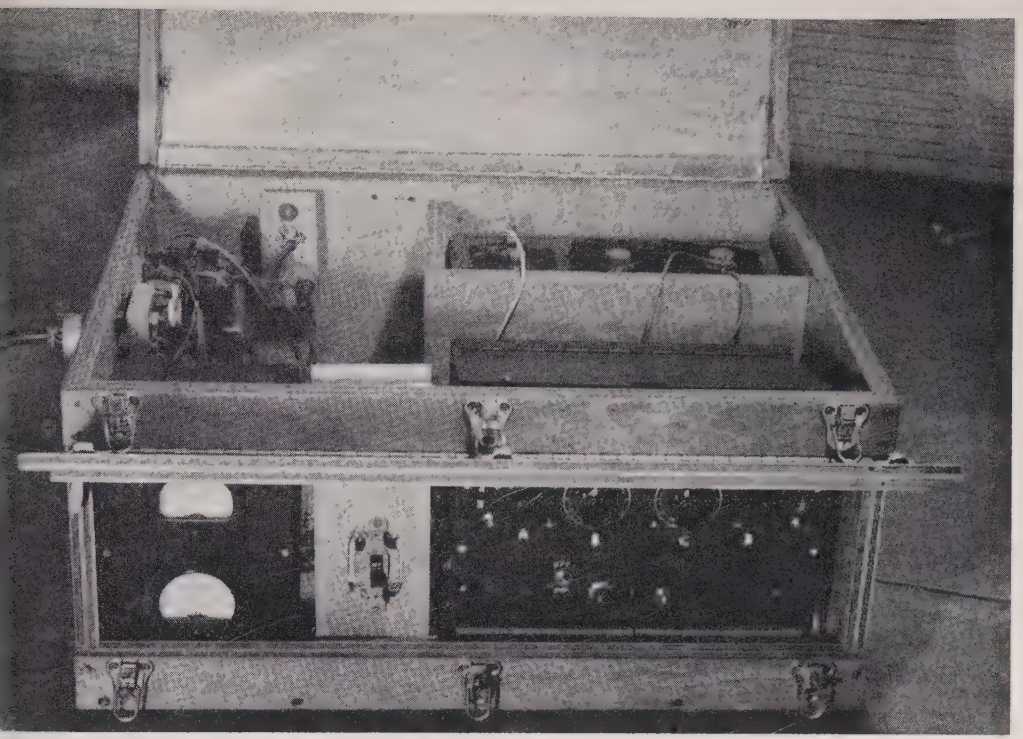

FIGURE 2. Current interrupter used with 2,500-watt direct current generator to produce interruption frequencies between 20 and 300 per minute.

our runs in each direction usually consti- d a test of a single design or frequency. results of each run were recorded and the entage of the available fish captured was ulated. In all tests power was shut off when seine was within about 3 feet from the end ne run to avoid taking fish which had been ed against the enclosure. Fish were chased from the end of the enclosure before a run in the opposite direction was started. w lot of test fish was seined from the lake ediately before each trial. In most cases ast 100 bluegills with an average length pproximately 5 inches and 500 perch fin- ngs with an average length of about 1½ s were used. The more promising elec- arrangements and frequencies were sub- d to a series of such tests. No statistical urement of variation between tests or be- n runs within individual experiments was pted because the necessary assumptions not be met.

ur electrode arrangements were tested at volts and interruption frequencies of 60 minute and 180 per minute in the test sure. A horizontal electrode system consisting of 30-inch lengths of braided copper shielding threaded over a 14-2SJ neoprene cable and spaced 6 inches apart was constructed and wired to provide opposite polarity on alternate electrodes. This design was similar to that used by Haskell (1954). The line of electrodes was suspended midway between the bottom and surface for fishing operations. Fish were repeatedly observed passing through the seine close to the surface and close to the bottom where they apparently followed equipotential surfaces of the field. Bluegills rolled on their sides and passed through the field easily.

A second design of electrode arrangement consisted of 30-inch lengths of Number 50 steel sash chain suspended from the surface in a line and spaced on 18-inch centers with each alternate drop chain of opposite polarity. Fish were frequently observed passing through the seine between the electrodes, again apparently following the equipotential surfaces which were now vertical.

An electrode system consisting of a single row of suspended chains spaced 18 inches apart and a row of 8- by 10-inch hardware grids floating behind and between the vertical electrodes was the third design tried. The

vertical electrodes were negative and the floating electrodes were positive. It was hoped that this arrangement would attract fish to the surface where recovery would be more effective. The "escape route" through this seine was somewhat more complex than in other designs, since the fish had to pass between the vertical electrodes and then under the floating grids in order to get through.

The last design consisted of two rows of chains suspended vertically and 24 inches apart with the chains in each row 18 inches apart. All the chains in the leading row were positive and all chains in the following row were negative. This design had no direct escape routes through the field.

Of these four arrangements, the double-row vertical electrode system was the most effective. The average percentage of capture with the various designs operated at 230 volts and 180 interruptions per minute ranged from 1.6 to 23.0 percent with bluegills and 2.0 to 9.7 percent with perch fingerlings (Table 1).

TABLE 1.—*Average percentage of available fish caught per run with four electrode arrangements, operated at 230 volts direct current and 180 interruptions per minute*

Electrode arrangement	Number of runs	Average percentage capture per run	
		Perch fingerling	Bluegill adult
Horizontal	8	2.0	1.6
Single-row vertical	6	4.9	2.6
Floating grid and vertical	6	5.2	1.4
Double-row vertical	40	9.7	23.0

In order to evaluate the influence of changed frequencies of interruption, the double-row vertical electrode was used in a series of trials with pulses which ranged from 20 to 300 per minute (Table 2). The first set of trials was run in 1956 with lower frequencies and the second set with higher frequencies in 1957. Water conductivity was not determined but tests were run at a temperature of 67-87° F., a total alkalinity of 84 p.p.m., and a pH of approximately 8.7. Trials at the various frequencies indicated that the higher ranges (180 and above) were most effective. Comparison of the three highest frequencies showed no clear-cut advantages so 240 interruptions per minute was chosen for subsequent field trials.

TABLE 2.—*Average percentage of available fish cap tured at various interruption frequencies by the double-row vertical electrode design operated a 230 volts*

Interruption frequency[1]	Number of runs	Average percentage capture per run	
		Perch fingerling	Bluegill adult
1956 trials			
20 per minute	16	6.4	8.7
60 per minute	24	7.2	18.5
180 per minute	40	9.7	23.0
1957 trials			
180 per minute	14	4.3	2.7
240 per minute	14	4.2	5.1
300 per minute	8	3.7	2.6

[1] The duty cycle at all interruption frequencies was 0.50 except at 20 and 60 interruptions per minute when duty cycle was 0.80.

In 1956 the test enclosure was set up so that its long axis was perpendicular to shore It was noted that in trial runs about twice a many fish were taken on shoreward runs as on off-shore runs. During 1957 the enclosure wa set up with the long axis parallel to shore There was no apparent difference in the catch from runs in the two directions but all runs caught less fish than in the previous orienta tion. These differences in results between sea sons and different orientation of the trial runs are attributed to behavior patterns of the fish which were herded toward shore, away from shore, or parallel to shore. Confinement of the fish in an enclosure and variations caused by orientation of the runs prevents use of the data from the trials to determine efficiency of field models of the seine when employed under normal operating conditions.

FIELD TRIALS OF SEINE

After the enclosure trials and some additional experimentation with the test seine dragged through the water on foot and supplied by a 300-foot cable from the beach, it was apparent that both the seine and its power supply should be mounted on a boat. A seine was therefore constructed which could be attached to a boat by means of a short bowsprit and lateral booms. The double-row vertical electrode arrangement with the positive electrodes in the leading row was supported from 10-foot booms hinged to the bowsprit and buoyed at the end by plastic foam floats. The booms were swept slightly forward to form a shallow "V" with a maximum fishing width of 18 feet (Figur

). The complete seine contained 14 pairs of lectrodes which drew a total of approximately 0 amperes of current at 230 volts when fished t the maximum depth of 30 inches. Fourteen airs appeared to be the maximum number hich could be used because the generator ould not carry a larger load and two pick-up ien could not cover a span greater than 20 eet. The seine was operated by two men who aded alongside, pulled the boat, and picked the fish with dip nets. If the seine were to e used on soft or very rocky bottoms, one an would be required to operate the boat hile the two pick-up men rode in the bow.

Early catches with this seine were lower an had been expected on the basis of the reliminary trials. Observation indicated that e fish were herding ahead of the electrodes id escaping around the ends. Others escaped neath the seine, apparently following the anted equipotential surfaces which were rmed when the chain dragged at an angle as e seine approached the beach. Herding and capement were effectively reduced by the lition of 5-foot "tip-booms" (Figure 3) ounted at right angles to the main booms. These tip booms carried three negative electrodes and appeared to turn the fish back into the path of the seine. Escape from beneath the seine was controlled by the use of flat jointed stainless steel strips for the leading electrodes. These strips, which were rigidly hinged at the top in such a way that the upper section was prevented from slanting backward when the seine was under way, remained almost vertical even in shallow water. Stainless steel which did not corrode under operating conditions was used for all electrode construction. Early tests showed that electrodes of brass, iron, or tin-coated copper could not be used because severe electrolytic corrosion on the anodes reduced their effectiveness.

With tip booms and jointed electrodes, the seine captured fish of all available species in substantial numbers and in sizes down to less than 1 inch in length. Limited comparisons with a bag seine of equal width late in the 1957 season indicated that the bag seine could be expected to capture more fish on smooth bottoms, but that an electric seine embodying the general construction principles developed here would capture a large enough proportion of available fish to justify its use in quantitative

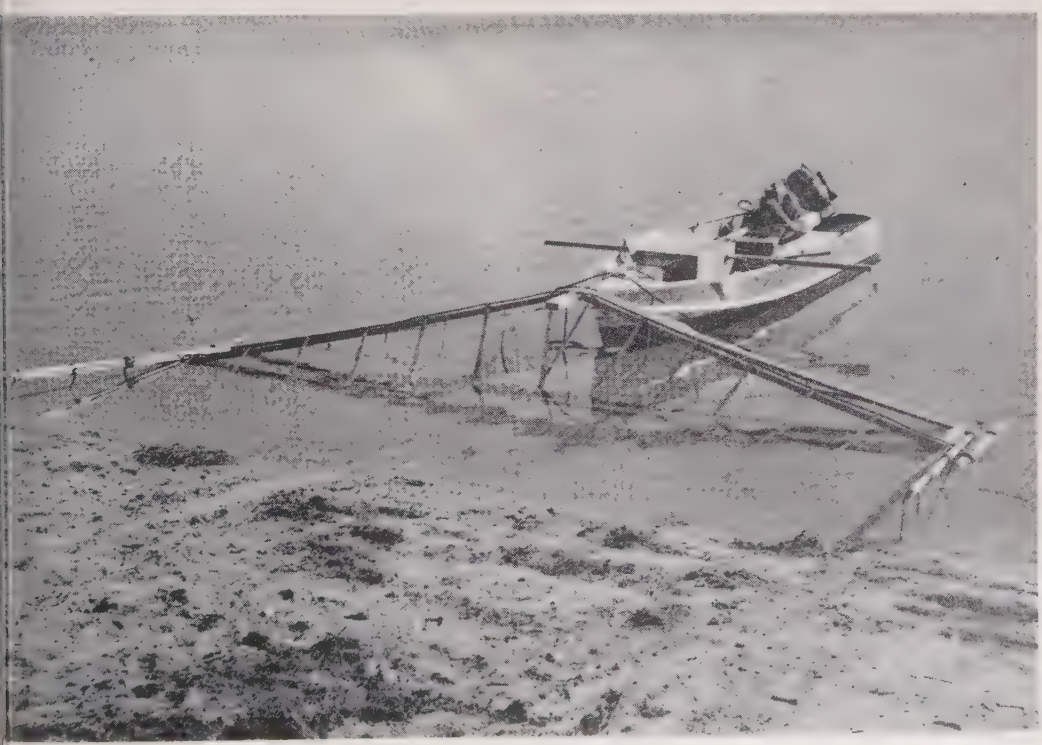

FIGURE 3.—Boat-mounted electrical seine employing hinged lateral booms and tip booms to support double vertical row electrode system.

problems as soon as levels of efficiency could be established.

The seine described above is mechanically adequate in that it will operate through heavy vegetation and over all types of bottom, but both portability and durability can be improved. Its principal electrical limitation is an inability to induce electrotaxis in more than a small percentage of the fish, while immediately narcotizing the remainder. The recovery of the fish is therefore badly hampered in turbid water or heavy vegetation. This low level of electrotactic response may be associated with the relatively high voltages used. Taylor, Cole and Sigler (1957) point out that electrotaxis occurs at a lower voltage than is required to produce electronarcosis and that the range of voltage between the electrotactic and electronarcotic levels may vary with the size of fish. It is therefore possible that in the present experiment only a small percentage of fish exhibit electrotaxis because the range between the electronarcotic and electrotactic levels was very short. It is also possible that the susceptibility of the fish to narcosis is variable and that the electrotactic voltage level for most of the fish was slightly below the 230 volts used.

In its present state of development, this seine should be useful for assessing relative abundance of shore fish especially as a supplementary sampling tool in areas where other gear is not usable. Its usefulness as a quantitative tool will depend on establishment of efficiency factors which compensate for water quality, orientation with reference to the beach, and other factors which influence the rate of catch.

LITERATURE CITED

California Marine Research Committee. 1950. Electrical stimulation of fish in sea water. *In* Cal. Coop. Sardine Res. Program, Prog. Rept., 1950, pp. 46-47.

Haskell, David C. 1954. Electrical fields as applied to the operation of fish shockers. N. Y. Fish and Game Jour., Vol. 1, No. 2, pp. 130-170.

———. and William J. Adelman, Jr. 1955. Effects of rapid direct current pulsations on fish. N. Y. Fish and Game Jour., Vol. 2, No. 1, pp. 95-105.

Taylor, Glenn N., Larry S. Cole, and William S. Sigler. 1957. Galvanotaxic response of fish to pulsating direct current. Jour. Wildl. Management, Vol. 21, No. 2, pp. 201-212.

Tester, Albert L. 1952. Notes on the response of a tropical fish (*Kuhlia sandvicensis*) to interrupted direct current. U. S. Fish and Wild. Serv., Spec. Sci. Rept., Fish. No. 91, pp. 69-83.

Book Reviews

TREATISE ON LIMNOLOGY. VOLUME 1. GEOGRAPHY, PHYSICS, AND CHEMISTRY. *By G. Evelyn Hutchinson, John Wiley & Sons, Inc., New York. 1957. xiv + 1015 pp. $19.50.*

A. Birge once characterized limnology as "a union science and beauty." Now Professor Hutchinson, the first paragraph of his excellent work, makes ste to spell out the beauty of his science: Lakes id to be grouped in lake districts because lake- ming agencies acted regionally rather than at lated points; we have available then for study ups of lakes which differ from each other in cer- n respects and, within each group, individual es which retain the group's characterizing traits t which differ among themselves in other traits. is this "diversity in unity" to which Professor tchinson assigns the responsibility for limnology's culiar fascination.

In his preface, the author addresses the book "to l who are professionally concerned with liminolgy," t also to biologists and oceonographers. It is not ended as a textbook, but rather as a reference book ich sets forth the detailed knowledge of limnology the present time for the use of the professional. order that its value be not lost to all except the anced limnologist, however, the author has in- ded a very welcome summary at the end of each pter, which should assist in consolidating the de- l of the chapter proper, as well as fulfilling his pe of providing the elementary student with a ple account. The scope of his work is broad, not y in time, in geography, and in the number of ciplines employed, but also in the immense detail the author's study and own experience. This ume is presented as the first two; as its title rly states, it is concerned with physical aspects limnology. It will probably be utilized less by ery scientists and other biologists than will be second volume, which, it is promised, "will deal h limnobiology and ecological, typological, and tigraphic problems of lake development."

The first chapter quite logically is concerned with origin of lakes; nearly 100 types of lakes are cribed on the basis of type of basin formation. forces which form a lake basin determine the and shape of the lake, which then are determin- sants, to some extent, of the physicochemical and logical nature. Furthermore, by using a classifica- system based on the basin-producing agencies, world's lakes may thus be treated in districts. The criptions of types are well illustrated by drawings the processes involved, and by maps and photo- hs of examples; at least one example is given each type. The individual types are grouped larger categories such as basins formed by anic activity, landslides, glacial activity, etc. Cer- of the better-known groups of lakes, such as e in the Engdish Lake District and the Great es are given special descriptive treatment. The nd chapter completes the subject of lake raphy. The more important morphometric fea- s are described and formulae for their computa- given; examples of lakes possessing unusual nitudes of these features are described or listed. The morphology of lakes is discussed in sections on shoreline form, insulosity (percentage of area in islands), and in some detail the processes of shoreline and basin form development.

The subject of physical limnology is introduced with a chapter on the physical properties of water, thermal and density relationships, dissociation, and a discussion of the isotopes of hydrogen and oxygen and the consequent kinds of water molecules naturally occurring. A short chapter on water balance in lakes primarily discusses the relationships between a lake's sources of water and the subsequent paths of removal. The chapter on hydromechanics of lakes covers the subjects of turbulence, currents, seiches, and waves. The extensive work of Mortimer particularly upon internal seiches is given considerable detailed attention. In this chapter the author begins to lay down the framework for the study of lake ecology (to be have profound effects upon the chemical and biolog- covered in the next volume), for water movements ical events occurring in lakes. The use of mathematics is extensive in this chapter, but much in formation may be gained by the non-mathematical reader since the author's word descriptions are clear and informative.

In a section on optical properties of lakes, Professor Hutchinson first considers the character of solar and sky radiation, then continues to a consideration of reflection, back radiation, and net radiation surplus the result of which is heating. A great deal of attention is given to the absorptive properties of pure and lake waters, much of this, of course, treated mathematically. An excellent section on water color —its characterization, its absorptive properties, and its probable sources—is given in this chapter.

The progress modern limnology has made is perhaps best exemplified in the chapter on thermal properties, for observations on thermal effects in lakes were among the earliest made. The author has clarified Forel's classification of types of lakes based on the manner of stratification, and Whipple's "order" classification of thermal types. He stresses the effects of altitude as well as latitude on lake depth, and the differences between an oceanic and a continental climate in their effect upon the manner of stratification, and describes many other facets of temperature, phenomena. The subjects of heating the hyplimnion, the peculiar aspects of meromixis, and heat budgets are discussed in some detail. An interesting section on lake ice completes this chapter, and the portion of the book concerned with physical limnology.

Ten more chapters comprise the remainder of the volume, all devoted to limnochemistry. In these chapters the author continues to build a framework for biological studies in lakes. The introduction to the subject is presented in the chapter on the chemical composition of rain and surface waters. A rather extensive consideration of oxygen illustrates the author's contention that more can be learned about the nature of a lake by a series of oxygen determinations than from any other chemical data; very little of biological significance is included in this chapter on

this biologically important element, but the author no doubt will return to consider oxygen in the second volume. Distributions of oxygen during circulation periods, under unstratified and stratified summer conditions, in winter and under certain special circumstances (such as at high altitudes) and in meromictic lakes are discussed, including a consideration of oxygen deficits of various kinds and their metabolic significance.

Considerable attention is given to carbon dioxide and hydrogen ion concentration (including solubility of carbon dioxide in various waters), the $CO_2 — HCO_3 — CO_3 =$ system, and distribution of carbon dioxide in various type of lakes and vertically within a lake. The reciprocal relationship between increase of carbon dioxide and decrease of oxygen in the hypolimnion, is discussed.

Before taking up the individual nutrient elements, the author first considers redox potentials and their effect upon the iron cycle. The virtual insolubility of ferric iron, and the dependence of the ferrous form upon low redox potentials emphasizes the importance of this measurement as an indication of the oxidation-reduction state. Several more chapters describe in detail the cycles in lake of phosphorus, sulfur, silica, nitrogen, and several minor metallic elements.

Volume I ends with a short chapter on organic matter in lakes, a chapter which discusses methods for determination, sources of organic matter, and its composition; but main emphasis is placed on the lack of knowledge on this subject and difficulties in obtaining it.

Of no small significance in this volume is the large and extremely valuable bibliography. An index of lakes and a detailed general index is also included. However, a glossary of limnological terms would have been a useful addition.

The second volume, which will be concerned with biological limnology, will no doubt be awaited with a great deal of anticipation by aquatic ecologists.

THOMAS F. WINTERS

University of Minnesota,
St. Paul, Minnesota.

MICROBIOLOGY. *An Introduction. By Ernest Gray. Philosophical Library, Inc., 15 East Fortieth Street, 16, New York. 175 pp., 25 figures. 1955. $3.75.*

The author, who is Chief Bacteriologist at Bayer's Biological Institute, Exning, England, has prepared an interesting and easily readable resume of the entire field of microbiology. It is not a text nor does it consider in great detail any particular aspect of microbiology. Rather it attempts (and the reviewer thinks quite successfully) to present a general view of the entire field with emphasis on interrelationships or, as the author puts it, "stressing—ecology and at the same time pointing to the invaluable work of pioneers many of whom are unjustly forgotten." If the memories of training in microbiology are becoming dim, this is a good book to read to review the old and to bring you up into antibiotic period. The chapters on microbiology of soil and applied microbiology are especially interesting. There is a bibliography of 85 references plus a list of texts and a good index. The book is well printed and free from typographical errors.

JOHN B. MOYLE

MANUAL OF AQUATIC PLANTS. *By Norman C. Fassett with Revision Appendix by Eugene C. Ogden. University of Wisconsin Press, Madison, Wisconsin. 405 pp. illust. 1957. $6.50.*

This is a reprinting of Fassett's classic and well illustrated book on aquatic plants with a "Revision Appendix" by Dr. Ogden. It allows fisheries workers and others to identify aquatic and marsh plants in the region from Minnesota to Missouri and eastward to the Gulf of St. Lawrence and Virginia and apply the presently accepted names. It is unfortunate that the manual was not completely reset and the corrections and additions included in the main body of text. As it stands it is often necessary to refer to both the text and Revision Appendix to ascertain proper identification and name. Many of the changes from the earlier edition are in nomenclature and bring the scientific names into harmony with those in the recent Eighth Edition of *Gray's Manual.*

JOHN B. MOYLE

FISHERIES, FISH FARMING, FISH MANAGEMENT. *Edited by Ken McLeod. Washington State Department of Fisheries. 148 pp., illust. Dec. 1948.*

This readable and well-designed and printed book represents an approach to fish management different from that of most State publications, in that its goal is the presentation of the possibilities whereby private industry may participate with government in the management of coastal marine waters and estuaries. As Milo Moore points out in the introduction, fish farming has been more successful in countries where population pressure has brought about private use of aquatic resources than it has been in the Western Hemisphere. Fourteen of the 16 chapters are by members of the Washington Department who summarize the present status of fisheries research and management and indicate how this information is applicable to management of coastal waters. General background in marine fisheries biology is provided by two chapters that have been reprinted from *The Sun, the Sea and Tomorrow* by F. G. Walton and Henry Chapin. Among the subjects considered are; the history of fish farming, oyster farming, clam farming, history and status of the west-coast salmon fishery, fertilization of waters, fish farming and hatchery methods, and international aspects of Pacific coast fisheries.

This is a useful and thoughtful book and one in which Milo Moore, Clarence Pautzke, Ken McLeod and the other authors bring together much scattered information and make it available to the general reader. But it is more than a book for public education for it is well documented and will be of considerable use to professional fisheries workers. It is heartening in this time of a spate of publications that the Washington Department has taken time to summarize and take a good look toward the future.

JOHN B. MOYLE

Shorter Papers and Notes

Sexing of Channel Catfish

Accurate designation of the sex of channel catfish, *Ictalurus punctatus* (Rafinesque), can be made by external examination of the urogenital region with the aid of a probe. In the female catfish the urinary and genital ducts have separate external openings, while in males these ducts have only one common opening (Figure 1).

This differentiation of the sexes is apparent in several species of fish but with a varying degree of manifestation. The characteristics are more pronounced in adult fish and during the spawning season (Figure 2). During a life history study of the white bass, *Roccus chrysops* (Rafinesque) in Spirit Lake, Iowa, it was discovered that the sex could be determined from external characters (Sigler, 1948).

A practiced observer, equipped with a suitable probe, can sex the following species: gizzard shad, *Dorosoma cepedianum* (Le Sueur); bigmouth buffalo, *Ictiobus cyprinellus* (Valencinennes); smallmouth buffalo, *Ictiobus bubalus* (Rafinesque); black bullhead, *Ictalurus melas* (Rafinesque); channel catfish, *Ictalurus punctatus* (Rafinesque); flathead catfish, *Pylodictis olivaris* (Rafinesque); white bass, *Roccus chrysops* (Rafinesque); yellow bass, *Roccus mississippiensis*... (Jordan and Eigenmann); northern rock bass, *Ambloplites rupestris rupestris* (Rafinesque); walleye, *Stizostedion vitreum vitreum* (Mitchill); yellow perch, *Perca flavescens* (Mitchill); freshwater drum, *Aplodinotus grunniens* (Rafinesque). The wide range of genera listed above suggests that the technique can be applied to many other species.

LITERATURE CITED

Sigler, William F. 1948. Determination of Sex of the White Bass, *Lepibema chrysops*, from External Characters. Copeia, No. 4, December 31, pp. 299-300.

Tom Moen

Iowa Conservation Commission
Spirit Lake, Iowa

Figure 1.—The relative position of anal region openings occurring in a male and female channel catfish are shown with probes (blackened match sticks for photographic purposes) inserted in the respective apertures.

Figure 2.—During the spawning season the determination of the sex of channel catfish by the number of external openings is often possible with the naked eye but probing is recommended for accuracy.

An 8-Year-Old Sockeye Salmon from Connecticut

On April 20, 1957, the opening day of the trout fishing season in Connecticut, an angler captured a 20-inch, 3-pound sockeye salmon in East Twin Lake, a 550-acre lake near the village of Canaan, Connecticut. Approximately ten years preceding this time, there was a rather popular but limited fishery for this species in that lake. The presence of sockeye salmon in East Twin Lake was first called to the attention of the Board of Fisheries and Game during the fall of 1936 when large numbers were reported spawning in localized shallows. The circumstance surrounding the introduction of this species is not known for certain, but there are records of plants of landlocked salmon and lake trout in this impoundment from 1876 through 1907. Though these records list "landlocked salmon", they do not indicate whether these fish were of an Atlantic or a Pacific genus.

Webster (1942) reports that the breeding season for the sockeye in Connecticut in the years 1936 through 1939 extended from mid-October through early December. He further states that the mature adults of this population attained a size of 14.0 to 16.5 inches in total length just prior to spawning.

In 1949-1950, however, it appeared from the scarcity of adults appearing on the spawning beds that the numbers of fish were dwindling to the point of extinction and, therefore, the species was given complete protection. Thus, when one of the Department's field men checked the angler who had captured this fish it was confiscated and subjected to close examination. The fact that a sockeye salmon had not been reported from this body of water for the past six or seven years was indeed intriguing and its relatively large size suggested rapid growth or old age. Length and weight of the specimen were obtained and a scale sample taken. It was determined that it was an immature female, and as suspected from its size, it was an exceptionally old fish.

The writer has interpreted from scale reading that the fish was of the 1949 year class. There were eight annuli or winter marks on the readable scales with the eighth appearing on the scale margin. The assignment of the last annuli to the margin is logical inasmuch as this fish was captured in the spring prior to the onset of the 1957 growing season. Figure 1 is a photograph of a scale from this specimen with the writer's interpretation of the position of the annuli or winter marks. The first two years of growth are rapid, followed by a gradual crowding of growth increments. The doubtful area from the standpoint of interpretation is that of the presence and position of the seventh and eighth annuli. The increment made during the 1956 growing season indicates the period of slowest growth. Inasmuch as there would be no resumption of growth by April 20 in this latitude, it is reasonable to assume that the position of the last annulus is on the margin. It is also probable that this fish did not spawn as there is no indication of a spawning mark on the scale.

The age and life span of both the anadromous form of the sockeye and the land-locked kokanee are fairly well documented in fisheries literature. Most landlocked forms attain sexual maturity, spawn and die in their third or fourth year. In personal communication, Mr. Kenneth Mosher of the U. S. Fish and Wildlife Service, Seattle, Washington, states that of around a thousand landlocked sockeye and kokanees from lakes in the northwest he examined, only a few six-year-old fish and one seven-year-old were found. This latter specimen was 18 inches long. He further states that the sea-run type are predominantly four to six years old with probably some seven and eight-year-old individuals appearing in the more northern area of Alaska.

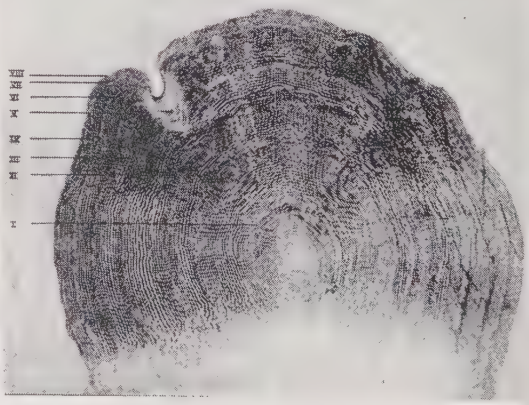

FIGURE 1.—Sockeye salmon scale indicating the writer's interpretation of annuli.

(*Photograph by C. W. Wilde*)

A similar photograph has been examined by several persons known to have an authoritative background in the age analysis of salmonid fishes and who have a considerable amount of familiarity with the life history of the genus *Oncorhynchus*. There was some slight disagreement in interpretation, but the majority of those who have examined the scale are in agreement with the number and position of the annuli as shown in Figure 1.

Appreciation is expressed to the following for their comments and opinions regarding the age analysis of this scale specimen: Dr. John R. Greeley, New York State Conservation Department; Mr. William L. Peck, U. S. Fish and Wildlife Service; Dr. Willis H. Rich, Stanford University; Mr. Kenneth Mosher, U. S. Fish and Wildlife Service; Dr. Lauren R. Donaldson, University of Washington and Dr. Ted S. Koo, University of Washington.

LITERATURE CITED

WEBSTER, DWIGHT A. 1942. The life histories of some Connecticut fishes. Section III, A Fishery Survey of Important Connecticut Lakes. Conn. Geol. and Nat. Hist. Surv. Bull., No. 63, pp.

JAMES P. GALLIGAN

Connecticut Board of Fisheries and Game
Hartford, Connecticut

Fishing in Pennsylvania

There are 700,000 fishermen who buy fishing licenses in Pennsylvania and some 4,600 miles of fishable trout streams on the Commonwealth's stocking list. In addition there are hundreds of miles of big rivers and we are building new lakes at the rate of 10 each three years. Because of a vigorous program of cleaning up contaminated waters, there is now more fishing water in Pennsylvania than there has been for many years. We are also engaged in an active program for obtaining adequate public access to our larger waters.

The Fish Commission operates eight hatcheries, fosters a number of research activities and has a new research center at Benner Spring near State College.

Extract from Welcoming Address to 88th Annual Meeting by GOVERNOR GEORGE M. LEADER of Pennsylvania.

Variability of Infection of Black-Spot Parasite (Neascus spp.) in Some Cyprinid Fishes

The digenetic trematode known as the black spot parasite (*Neascus* spp.) is widely distributed in the metacercarial stage among many different species of fishes. Several species of this genus form characteristically pigmented cysts in the integument while others form non-pigmented cysts within the internal organs of the host fish. Some species apparently occur in only one host fish while others may be found scattered over a number of different host species. The lack of detailed work on this group of fish parasites and the difficulties in dissecting and identifying the immature forms have resulted in little published information on host specificity. The general life history of the group, however, has been described by several workers (Van Cleave and Mueller, 1934; Hunter, 1942; Fischthal, 1947, 1950, 1952).

Four collections of several species of minnows from small streams in Pennsylvania exhibited a noticeable difference in the degree of infection by this parasite. The blacknose dace (*Rhinichthys atratulus*), the longnose dace (*Rhinichthys cataractae*), and the creek chub (*Semotilus atromaculatus*) all showed a heavy infection. The pearl dace (*Semotilus margarita*), however, carried a very light infection. Two of these collections were from Slab Cabin Creek, Centre County, Pennsylvania, in the Susquehanna River drainage; the other two collections were from Six Mile Run, Warren County, Pennsylvania, in the Ohio River drainage.

The number of black-pigmented cysts in the skin of each fish was counted and the degree of infection was compared between fish of different species, total lengths, sex, and between fish taken at different localities and on different dates. There appeared to be no essential difference in the number of parasites occurring in the two sexes. The size of the fish and the number of parasites showed very little correlation, although a detailed analysis was not

---

[1]Authorized for publication on March 19, 1959 as paper No. 2351 in the journal series of the Pennsylvania Agricultural Experiment Station.

TABLE 1.—*Percentage of fish infected with* Neascus *metacercariae and mean number of parasites per fish in four species of cyprinids from two streams in Pennsylvania.*

Species of cyprinid examined	Number of fish examined	Percentage of fish infected	Mean number of parasites per fish	Number of fish examined	Percentage of fish infected	Mean number of parasites per fish
			SLAB CABIN CREEK			
	May 12, 1958			September 23, 1958		
Blacknose dace	11	100	33.6	64	96.9	16.1
Longnose dace	26	88.5	20.8	102	100	17.0
Creek chub	15	100	66.9	95	100	33.4
Pearl dace	12	25.0	1.0	10	50.0	0.7
			SIX MILE RUN			
	September 4, 1957			October 20, 1958		
Blacknose dace	95	50.5	6.4	41	58.5	17.8
Longnose dace	15	100	32.2	20	100	18.7
Creek chub	76	64.5	14.7	40	67.5	33.1
Pearl dace	44	22.7	0.5	10	50.0	2.9

conducted because of the limited number of fish and the large variation in the frequency of occurrence of the parasites. There were some differences noted in the degree of infection in the different collections, but the most obvious difference was the low incidence of infection in the pearl dace both as to the percent of fish infected and the number of parasites occurring in the fish (Table 1).

A more accurate identification of the species of *Neascus* involved would undoubtedly shed more light on the relationship between the parasite or parasites and these different host fishes. However, because of the variation in life history between morphologically similar larval forms (Hunter, 1942) and the lack of adequate facilities to isolate and rear these larval forms to the adult stages, completion of this study is not anticipated at the present time.

LITERATURE CITED

VAN CLEAVE, HARLEY J. AND JUSTUS F. MUELLER. 1934. Parasites of Oneida Lake Fishes. Part III. A biological and ecological survey of the worm parasites. Bull. New York State Coll. of Forestry, Vol. 7(1); p.p. 161-334.

HUNTER, GEORGE W. III. 1942. Studies on the parasites of fresh-water fishes of Connecticut. A fishery survey of important Connecticut lakes. Conn. Geol. and Nat. Hist. Surv., Bull., Vol. 63; pp. 228-288.

FISCHTHAL, JACOB H. 1947. Parasites of northwes Wisconsin fishes. I. The 1944 survey. Trans Wis. Acad. Sci. Arts and Ltrs., Vol. 37; pp 157-220.

——— 1950. Parasites of northwest Wisconsi fishes. II. The 1945 survey. Trans. Wis. Acad Sci. Arts and Ltrs., Vol. 40; pp. 87-113.

——— 1952. Parasites of northwest Wisconsi fishes. III. The 1946 survey. Trans. Wis. Acad Arts and Ltrs. Vol. 41; pp. 17-58.

EDWIN L. COOPER
JOHN K. ANDERSEN

The Pennsylvania State University
University Park, Pennsylvania

* * * * * *

Please don't hold back those views to th point of frustration . . . send them along fo the Newsletter. Should you wish to expoun on any issue pertinent to the welfare of th Society, or the profession, we will gladly ac just the type to fit in your piece. The office feel much can be gained by open expressio of views.

E. A. SEAMAN

Secretary-Treasurer
American Fisheries Society

Effects of Kraft Paper Wastes on a Montana Stream

It has frequently been found that the black liquor wastes from the Kraft or sulphate process paper mills are toxic to fish and bottom invertebrates of streams. The following observations on the effect of pollution of this kind in the Clark Fork River, near Missoula, Montana, may be useful to others confronted with this problem.

In November 1957, a paper mill producing cardboard by the Kraft (sulphate) process began operating on the Clark Fork River about 10 miles west of Missoula. The river here is about 150-200 feet wide, of moderate velocity and has a flow ranging from 1,200 to 40,000 c.f.s. (yearly average about 5,500 to 7,000 c.f.s.). It produces considerable sport fishing for rainbow trout (*Salmo gairdneri*), cutthroat trout (*Salmo clarki*) and mountain whitefish (*Prosopium williamsoni*), even though it is polluted by municipal and industrial wastes from Missoula. Original plans and specifications for the paper mill, as approved by the State Pollution Control authorities, required that the paper mill wastes be lagooned, but these lagoons had not been built when the plant began operating. Wastes were discharged directly into the river and usually flowed along the same side of the river as that on which the mill was located. At times, the water was discolored and soapy for several miles downstream.

Prior to the operation of the mill (in the spring and summer of 1957) bottom samples taken at a station about two miles downstream from the effluent outlet, and on the same side of the river, yielded 1,416 bottom organisms. Of these, 765, or 54 percent, were of types considered to be intolerant of pollution. In July 1958, after the mill had been in operation about seven months, the percent of sensitive organisms (of 951 taken) had dropped to 17 at the same station.

On July 31, dead fish were reported from the river. Aerial observations with ground counts indicated at least 33 concentrations of dead fish between the waste outlet and the mouth of Fish Creek, 25 miles downstream. Three of these concentrations, in which the fish were counted, showed 112, 116, and 121 dead fish. Species of fish found dead and dying were cutthroat trout (*Salmo clarki*), rainbow trout (*Salmo gairdneri*), mountain whitefish (*Prosopium williamsoni*), longnose sucker (*Catostomus catostomus subsp.*), largescale sucker (*Catostomus macrocheilus*), northern squawfish (*Ptychocheilus oregonense*), peamouth chub (*Mylocheilus caurinum*), and redside shiner (*Gila balteatus*). Examination of moribund fish by the state fish pathologist showed a typical syndrome of death by poisoning but no indications of disease.

To gather more conclusive data as to the cause of the kill, live cages of metal or wooden frames covered with cotton bobbinetting were placed in the stream at two stations above and five stations below the pulp mill. The cages had two compartments in which two sizes (three and seven inches) of hatchery-reared, rainbow trout were placed. Early in the morning of August 8th, black and foamy waste material was noted in the river. Dissolved oxygen in the river was adequate (6.6 p.p.m.). Caged fish, about a half mile below the effluent outlet, were visibly affected in three to four hours and all were dead in 30 hours. Two miles downstream, on the mill side of the river, 25 percent of the caged trout were dead in 30 hours. No mortality occurred in the cages upstream from the pulp mill.

In addition to the effects on bottom fauna and poisoning of fish, the Kraft mill wastes promoted a tremendous carpet-like growth of filamentous bacterial slime (*Sphaerotilus*) along the mill side of the stream for a distance of three-fourths of a mile below the discharge outlet. It seems evident that this growth needs continuous discharge of wastes, since cessation of discharge for a week brought about marked reductions in growth.

Wastes from this Kraft process paper plant are now being lagooned in two ponds of approximately 85 and 15 acres. The normal effluent flow, which contains no black liquor, is directed into the large, baffled pond, where a two to three month retention time is expected. Flows of black liquor waste, which are caused by infrequent plant breakdowns, are directed to the small lagoon, from which no surface outlet flow to the river is anticipated.

ARTHUR N. WHITNEY

Montana State Game and Fish Department, Missoula

JOHN C. SPINDLER

Montana State Board of Health Helena